STRUCTURE AND ENVIRONMENT

ARCHITECTURE, CIVIL ENGINEERING, ENVIRONMENTAL ENGINEERING, ENERGY AND GEOMATIC

No. 3/2019 vol. 11 PL ISSN 2081-1500 www.sae.tu.kielce.pl KIELCE UNIVERSITY OF TECHNOLOGY

Contents

structure

structure

environment

environment

Photos on the cover – author Agnieszka Wdowiak

www.sae.tu.kielce.pl
sae@tu.kielce.pl

The quarterly printed issues of Structure and Environment are their original versions

The Journal published by the Kielce University of Technology

PL ISSN 2081-1500

25-314 Kielce, al. Tysiąclecia Państwa Polskiego 7, tel. 41 34 24 581
www.wydawnictwo.tu.kielce.pl

Index Copernicus Value(ICV) za rok 2018 = 96.84

Kielce University of Technology
2019

INDEX COPERNICUS
INTERNATIONAL

structure

structure

IRYNA L. KRAVCHENKO
Kiev National University of Construction and Architecture
e-mail: kravchenko.il@knuba.edu.ua

Manuscript submitted 2019.08.07 – revised 2019.09.12,
initially accepted for publication 2019.09.30, published in September 2019

EXTERNAL AND INTERNAL FACTORS OF INFLUENCE ON DEVELOPMENT OF ARCHITECTURE OF NON-FORMAL EDUCATION ESTABLISHMENTS

ZEWNĘTRZNE I WEWNĘTRZNE CZYNNIKI WPŁYWAJĄCE NA ROZWÓJ ARCHITEKTURY PRZEDSIĘBIORSTW EDUKACYJNYCH

DOI: 10.30540/sae-2019-013

Abstract
The article sets out the main provisions on internal and external factors of influence on the development of architecture of non-formal education institutions. External factors are represented by a group of socio-economic factors, a technical (technological) factor, a number of political factors and an environmental factor. Internal factors that influence the development of the architecture of educational institutions include urban planning, architectural-planning, natural-climatic, and aesthetic. The article also presents the brief analysis of architectural projects done abroad and at the Theory of Architecture Department of Kyiv National University of Construction and Architecture to illustrate the impact of factors and to show main trends of architectural development of modern educational buildings.

Keywords: non-formal education, institutions of non-formal education, external and internal factors of influence, development trends of architecture for educational institutions

Streszczenie
W artykule określono główne elementy dotyczące wewnętrznych i zewnętrznych czynników wpływających na rozwój architektury pozaformalnych instytucji edukacyjnych. Czynniki zewnętrzne reprezentowane są przez grupę czynników społeczno-ekonomicznych, czynnik techniczny (technologiczny), szereg czynników politycznych i czynnik środowiskowy. Czynniki wewnętrzne, które wpływają na rozwój architektury instytucji edukacyjnych, obejmują planowanie urbanistyczne, architektoniczne, przyrodniczo-klimatyczne i estetyczne. W artykule przedstawiono również krótką analizę projektów architektonicznych wykonanych za granicą oraz w Katedrze Teorii Architektury Kijowskiego Narodowego Uniwersytetu Budownictwa i Architektury w celu zilustrowania wpływu czynników i ukazania głównych trendów rozwoju architektonicznego nowoczesnych budynków edukacyjnych.

Słowa kluczowe: edukacja pozaformalna, instytucje edukacji pozaformalnej, zewnętrzne i wewnętrzne czynniki wpływu, trendy rozwojowe architektury instytucji edukacyjnych

1. INTRODUCTION

Comprehensive interdisciplinary studies of factors affecting the development of the architecture of non-formal educational institutions cover a rather wide range of issues. Since non-formal education is an open educational subsystem, specialists from various sectors are involved in researching the problems of its formation and development, covering the problem from different perspectives: sociologistic, educational, historic, economic, statistical, etc. From the indicated branches accompanying the current research, basic concepts are borrowed concerning factors of influence and prerequisites for the development of non-formal educational institutions and are analyzed in accordance with the object of research. The object of this study is the institution of non-formal education. The subject of the research is the theoretical foundations of the formation of architecture of non-formal educational institutions in Ukraine and the modern world. Identification of the main factors of influence is one of the most important tasks in the context of the study.

Specialists from different countries dealt with the pedagogical and psychological problems of the formation and development of out-of-school and non-formal education. Joe Cullen, British psychologist noted that main factors are shaping lifelong learning are historical, demographic changes, globalisation and economic re-structuring, cultural changes, information and communications technology (ICT) and social networking [1]. Among Ukrainian specialist teachers, a lot of attention is paid to the development of out-of-school education as a part of the education process throughout life. So, doctor of pedagogical sciences Bykovskaya O.V. in her monograph presents the theoretical and methodological foundations of the formation of out-of-school education, based on the introduction of a competency-based approach [2]. The works of Nadezhda Pavlik highlight the theoretical and practical foundations of the organization of non-formal youth education. The analysis of pedagogical scientific literature conducted by Pavlik N. indicates that the organization of non-formal education is an important socio-political task for the most of developed countries. In addition, she emphasizes that non-formal education in Ukraine includes: out-of-school education, postgraduate education and adult education, civic education, school and student self-government, educational initiatives aimed at developing additional skills (computer and language courses, interest groups etc.), as well as the education of the elderly [3]. The work of Chagrak N. is devoted to the influence of demographic and socio-economic factors on the education of older people [4]. Basic sociological concepts, such as the social structure of society, which is a part of the socio-economic factor, are highlighted in the works of Verbets V.V., Subot O.A., Khristyuk T.A. [5]. Economists note the increasing role of human capital as one of the driving forces for the development of various levels of additional education [6].

Problems of development of the architecture of different level and purpose educational institutions are dealt with by architects-scientists.

Jeffery A. Lackney, architect PhD from American Institute of Architect (AIA), studying design principles for schools and community learning centres says: "A variety of social and economic factors have created an environment in which many educators recognize that learning happens all the time and in many different places. Formal educational program partnerships have been established with museums, zoos, libraries, other public institutions, as well as in local business workplace settings. Sharing school facilities with a variety of community organizations may fostering meaningful inter-organizational partnerships that can strengthen educational opportunities for learners." [7]. Lindsay Baker, the American architect who studies development of school architecture noted that schools are influenced by political and social movements, new technologies and trends, the growing awareness of what makes us learn better and thus our notions of what makes a great school are constantly shifting and adapting to new ideas [8]. Habibe Acar pointed out that main impact on learning process is learning environment. The scientist underlines the importance of the notions of environment and learning environments that influence especially the development of children and his study touches on the contributions of the physical environment to the learning process of children [9].

Russian architects-scientists Zmeul S.G., Tsitovich G.M., Stepanov V.I., and Ukrainian specialists Kovalsky L.M., Abyzov V. A., Naumov S.F., Sarkisov S.K., Smirnov V.V., Solobay P.A., Zhovkva O.I., Kovalskaya G.L., Merilova I.O., Tyshkevich O.P. and others also thoroughly dealt with the problems of the influence of various factors on the formation of architectural objects and educational complexes for various purposes. Among the factors influencing the development of architecture of educational buildings, socio-economic and socio-demographic conditions, the political factor, scientific and technological progress, historical-cultural and material-technical factors and the like are defined. Based on his own research, Abizov V.A. identifies the following groups of factors that determine sustainable development, such as: socio-economic; natural-geographical; urban; environmental; ergonomic; typological; technical; aesthetic [10, 11].

2. BASIC THEORY

During the study of the problems of formation of the architecture of non-formal education institutions (NFEI), a number of main factors affecting its development were identified. Factors are conventionally grouped into external and internal (Fig. 1). External factors are, as a rule, forces uncontrolled by the architect, which to a certain extent form a public demand for the creation of a new type of educational objects and, thus, influence the formation of the architecture object. External factors include: socio-economic, technical, political and environmental. Internal factors determine a number of regulatory, environmental and functional changes and requirements for the structure of educational buildings. The internal factors of influence on the development of architecture of educational institutions of various types and purposes include the following; town planning factor, architectural planning, climatic and aesthetic (Fig. 1).

Fig. 1. Basic scheme of the impact of external and internal factors on the development of architecture of non-formal education institutions.
Source: the scheme developed by Iryna L. Kravchenko according to own research results.

structure

External factors of influence. Among the main external factors in terms of the importance of influence, the first place is occupied by the ***socio-economic*** factor. It consists of the following conceptual subgroups: socio-ethnic structure, socio-demographic structure, socio-professional structure, social class and socio-territorial structure [5]. The author of the article already studied impact of socio-economic factor on architectural formation of non-formal educational institution buildings [12]. The study revealed that the most influential factors of this subgroup are: socio-demographic, which signals an increase in the proportion of adults and older people, against the background of a decline in the total population in the demographic composition of Ukraine; socio-professional, which is closely related to the problem of socialization of all segments of the population; socio-territorial, in fact, claims to strengthen the process of urbanization and requires the creation of an extensive network of non-formal education institutions by type, location and capacity; economic, which, in turn, is closely connected with the other positions listed above and speaks of the increasing role of human capital both in Ukraine and abroad.

External demographic reasons, first of all, include the demographic situation. The number of students is declining, the principles of their resettlement are changing, and new micro-districts are being built, where mainly young families move, which affects the increase in the number of students. At the same time, the centers of cities where the educational infrastructure is most developed are aging, very few children remain there. This trend is applicable to all cities of Ukraine, therefore, a thorough review of the functioning of all education networks is required: both preschool, and general, and additional, and vocational education and cultural institutions, the creation of network base institutions with branches. Thus, external causes drive new solutions [13].

Modern research by sociologists and educators suggests that now the structure of a person's life path is changing significantly. For example, cand. ped. sciences Chagrak N., analyzing the influence of demographic and socio-economic factors on the development of older people's education in the USA, notes that in addition to the aging of the nation, the so-called "blended life plan" has become another significant factor in the development of older people's education, which, in turn, was the result of demographic, social, and technological transformations in American society [4] (Fig. 2).

Fig. 2 Transformation of three-component structure of human`s way of life.
Source: the scheme developed by Iryna L. Kravchenko according to [4].

Such a tendency is also inherent in other countries and, gradually, is finding its ways in Ukraine. Among the economic components of this factor, the role of human capital is the most prominent. Human capital is a combination of qualities (knowledge, abilities, desires, motives, skills, psychophysical state, etc.) that are innate and acquired through investments in personal development, the implementation of which serves as a competitive advantage in the global labour market and is a source of additional profit [14]. In the modern world, countries that we call developed, give priority to investments in human capital. In the structure of the national wealth of the world community, it already makes 64%, ahead of natural capital (20%) and physical capital (16%). The share of human capital in countries such as Finland, Switzerland, Germany, Japan, and the United States reaches 80%. Human capital is a determining factor in the development of production, the introduction of new technologies; it ensures the rapid development of science and high social standards (culture, health, safety, and social protection). A special area of social life, due to which there is an increase in human capital, is the scientific and educational industry [6].

In general, the socio-economic factor determines the emergence of a public demand for the creation of a new type of educational environment, and, at the same time, of educational objects. The architecture of non-formal education institutions should reflect the public's commitment to the flexibility of educational scenarios and their corresponding spaces.

The second most important influence is the ***technical (or technological) factor***. This group of factors includes the following concepts:

- Transition to a post-industrial, information society;
- The emergence of a large array of the latest information technologies that simplify learning processes;
- A progressive increase in the amount of information, simplification of the way to access it and the rapid obsolescence of acquired knowledge;
- The urgent need for new professions and competencies in connection with scientific and technological progress;
- The emergence of the latest materials, design and construction tools that change approaches to the creation of architectural objects.

All this leads to fundamental changes in the information environment.

The next, third factor from the group of external factors, is the ***political factor***. The author puts the following aspects into this concept:

- Changes in political structure.
- Globalization of education in the world: goals and strategies for the development of education, the content of education, methods and criteria for evaluating the effectiveness of educational systems, and the like.
- Decentralization of power, the creation of united territorial communities. Providing them with financial resources and initiative powers.
- Education reform. Recognition of extracurricular and non-formal education as full-fledged links in the educational process.

Changes in the political system significantly affect the formation of architecture of educational institutions – from the era of totalitarianism, where monumental, static, centric and symmetrical compositional schemes prevailing, embodying the political idea, to modern architecture, with its various compositional forms, atriums, and the inclusion of the environment in the institution's function, which symbolizes openness and willingness to learn new things. The concept of globalization of education is derived from the concept of globalization, used in economic, political and social sciences since the beginning of the 90s. XX century. Globalization is a complex and baffling phenomenon. The political aspect of the impact of globalization on the development of education is determined by the spread of the ideas of neoliberalism on the educational policy of a significant number of states, and has the following manifestations: 1) erosion of the sovereignty of the nation state and the fullness of its authority in the field of educational policy, increased influence on the educational policy of international organizations (World Bank, World Bank Organization, International Monetary Fund); 2) denationalization of the educational sphere, privatization of educational services; 3) the transformation of forms of control in the field of education: from political, administrative to market, consumer control. The influence of the economic aspect of globalization on the development of education lies in its transformation into the subject of international trade. Another dimension of the impact of globalization on modern education is culture. In their totality, the political, economic and cultural aspects of the impact of globalization on the development of education make it possible to talk about the emergence of the phenomenon of globalization of education, by which we mean the process of convergence of the fundamental principles of the educational policy of national states in a number of parameters, primarily such as goals and strategies for the development of education, educational content, methods and criteria for evaluating the effectiveness of educational systems and the like. The concept of globalization of education was included in Ukrainian pedagogical science at the beginning of the XXI century in the context of studies of global educational policy and determination of strategic directions for reforming the educational system of Ukraine [15]. It is this factor that most critically affects the reorganization of the network of educational institutions of all types.

The fourth externall factor is ***environmental***. It includes: abiotic factors – components and properties of inanimate nature: temperature, illumination, humidity, pressure, etc.; anthropogenic factors – conscious and unconscious human intervention in natural processes, pollution and disturbance of the urban environment. These aspects, in the end, cause global climate change, which, in turn, directly affects the creation of architectural objects, especially their structural and engineering components.

Internal factors of influence. Internal factors that influence the development of architecture of non-formal educational institutions (NFEI) include: town-planning, architectural-planning, natural-climatic and compositional-shaped (see Fig. 1).

The first of these is ***the town-planning factor***, which is as follows:

- Location: in the city, district, quarter, village and the like;
- Renovation/re-functionalization: prevailing urban development; industrial areas that are not used;
- Transport and pedestrian accessibility;
- Proximity to major highways;
- The presence of park areas and green spaces;
- Requirements for the arrangement of a site for an educational institution.

Consideration of all these aspects should contribute to the selection of the optimal urban planning decision on the placement of the architectural object of the educational institution.

The second factor of this group is ***architectural-planning***. This internal factor of influence requires a balanced approach to the choice of architectural and planning solutions of the latest NFEI. The main aspects of this factor are:

- Typological aspect: the affiliation of the architectural object of the education institute to a certain typological link;
- Functional planning schemes: the corresponding educational level in the structure of the school, integrated institutions, integration into other public complexes;
- Adaptation of the existing fund for an educational institution;
- Capacity: groups, blocks, non-formal education complexes, etc;
- Appointment/direction: art, sports, scientific and technical, health, universities of the third age and the like;
- Ergonomics: furniture, equipment, general communication areas and the like.

The result of competent processing of factors of this group should be the optimal structural and functional models of institutions of the NFE and their cells, different in capacity and purpose.

The third factor from the internal factors of influence is the ***natural-climatic*** one. It includes several aspects: the climatic conditions of the region, the presence of relief and the possibility of its use in the project, hydrogeological conditions, landscape characteristics of the developed territory, the orientation of the educational institution, the presence of reservoirs and recreational areas. This factor obliges to consider when designing the conditions of a particular area.

The fourth factor is ***aesthetic*** and it is represented by three main aspects: the correspondence of the composition and image of the building to the purpose of the institution and the planning decision, the correspondence (or opposition) of the image of the building to the environment, and the colour issues, stylistic features etc. With a balanced approach to the design of NFEI, the consequence should be the choice of the optimal composition and image of the building of a non-formal educational institution.

3. RESULTS AND DISCUSSION

Solving the problems of our time, due to external and internal factors of influence, the architecture of non-formal education institutions is developing and creates certain trends in the design of institutions of additional education. The Department of Theory of Architecture of KNUCA (Kyiv National University of Construction and Architecture) conducts research in the field of theoretical foundations of architecture of public buildings and complexes (No. 67.01.18.0768/0117U005420) [16]. Within the framework of the current study, a number of major trends in the development of NFEI (non-formal education institutions) architecture were identified (Fig. 3).

The first and most important trend is **cooperation.** The trend is formed under the influence of a number of the above factors: socio-economic, political, environmental, urban planning, architectural-planning, with a review of the typological components. The indicated trend is popular and widely used in the design of educational institutions of a new generation in the following aspects:

- Cooperation of functions (Fig. 4);
- Various age groups (Fig. 4);
- Architectural planning techniques and approaches (Fig. 4, 5, 7);
- Architectural volume and landscape (Fig. 5 and 7).

A vivid example of this trend can be called the experience of the Netherlands in creating the so-called “extended schools” – public schools. The object is an example of the implementation of the “guardianship concept”, according to which the system of extracurricular education in the Netherlands works [17, 18, 19] (Fig. 4).

An illustration of the cooperation of architectural-planning techniques and the cooperation of architectural volume and landscape is the project of the qualification level “bachelor” developed at the

Fig. 3. Main trends of architectural development of non-formal education institutions (NFEI).
Source: the scheme developed by Iryna L. Kravchenko according to own research results.

Fig. 4. Culture Complex "De Nieuwe Kolk". Architects "De Zwarte Hond", Netherlands.
Source: the scheme developed by Iryna L. Kravchenko according to [17, 18].

Department of Architecture Theory of KNUCA (Kyiv National University of Construction and Architecture), which was performed by A. Malashenko on the theme "School of Arts in Kiev". In addition to taking into account internal factors, the project focuses on the environmental component of the building. The architectural volume optimally inscribed in the urban planning situation, with a sufficiently developed composition of the premises, remains a fairly compact structure. The space-planning structure of the building of the school of art allows you to create all the rooms for classes around the compositional and spatial core-atrium, which serves as a public media library and the main communicative node of the building. The project widely uses the method of flowing space, due to which the environment is also involved in the functional component of the school (Fig. 5).

The next trend is **in-depth specialization**. The term was proposed by the author and defines the saturation of the existing architectural and typological links of educational institutions with new functions that enhance the educational component of the institution by adding facilities that allow not only extracurricular activities, but also various activities for the implementation of adult education, introducing the world concept of "life-long education". So, since the educational institution already has a certain specialization, the addition of functional groups of rooms deepens precisely the educational specialization, making it wider and more accessible to a wider circle of consumers of various educational services. In this trend, the following links of the system of non-formal educational institutions (NFEI) are considered: NFEI – a preschool educational institution, especially in the case of embedding or

Fig. 5. The diploma project qualification level "Bachelor" – School of Arts in the city of Kyiv. Complied with student ABS-53a Malashenko A.D. Fragment of the project. The Department of Theory of Architecture of KNUCA, Kyiv, 2013. Leader: architect, Ph.D., associate professor Kravchenko I.L.
Source: the scheme developed by Iryna L. Kravchenko according to the project of Malashenko A.D.

extension of children's preschool institutions; NFEI-comprehensive school; NFEI – institution of higher and vocational education; NFEI – institutions of social protection of the population; NFEI – research institutions; NFEI – fitness and rehabilitation institutions. The main factors influencing this trend are socio-economic, technical, urban planning and architectural-planning in terms of typological compliance and functional-planning schemes.

The next trend, which is being considered, is due to the modern transformations of society and the functioning of architectural objects, is **renovation/ refunctionalization** (see Fig. 3). This trend in the current study is considered and formed at three basic levels: architectural object, development, territory. The trend is due to the action of such influence factors: socio-economic in terms of the economic aspect; environmental, in the aspect of adaptation of abandoned objects and territories to educational and public institutions; urban planning; aesthetic, when the presence of historical or former industrial buildings and structures in the complex of the educational institution creates additional aesthetic appeal of the object of the educational institution. The project of the qualification level "master" developed at the Department of Architecture Theory of KNUCA, which was completed by V. Muleeva on the topic "Methods of the renovation of children's out-of-school establishments in the conditions of historical development", presents a solution that allows using the certain means of renovation (reconstruction) to integrate the art school into the historical development of Kiev (Fig. 6).

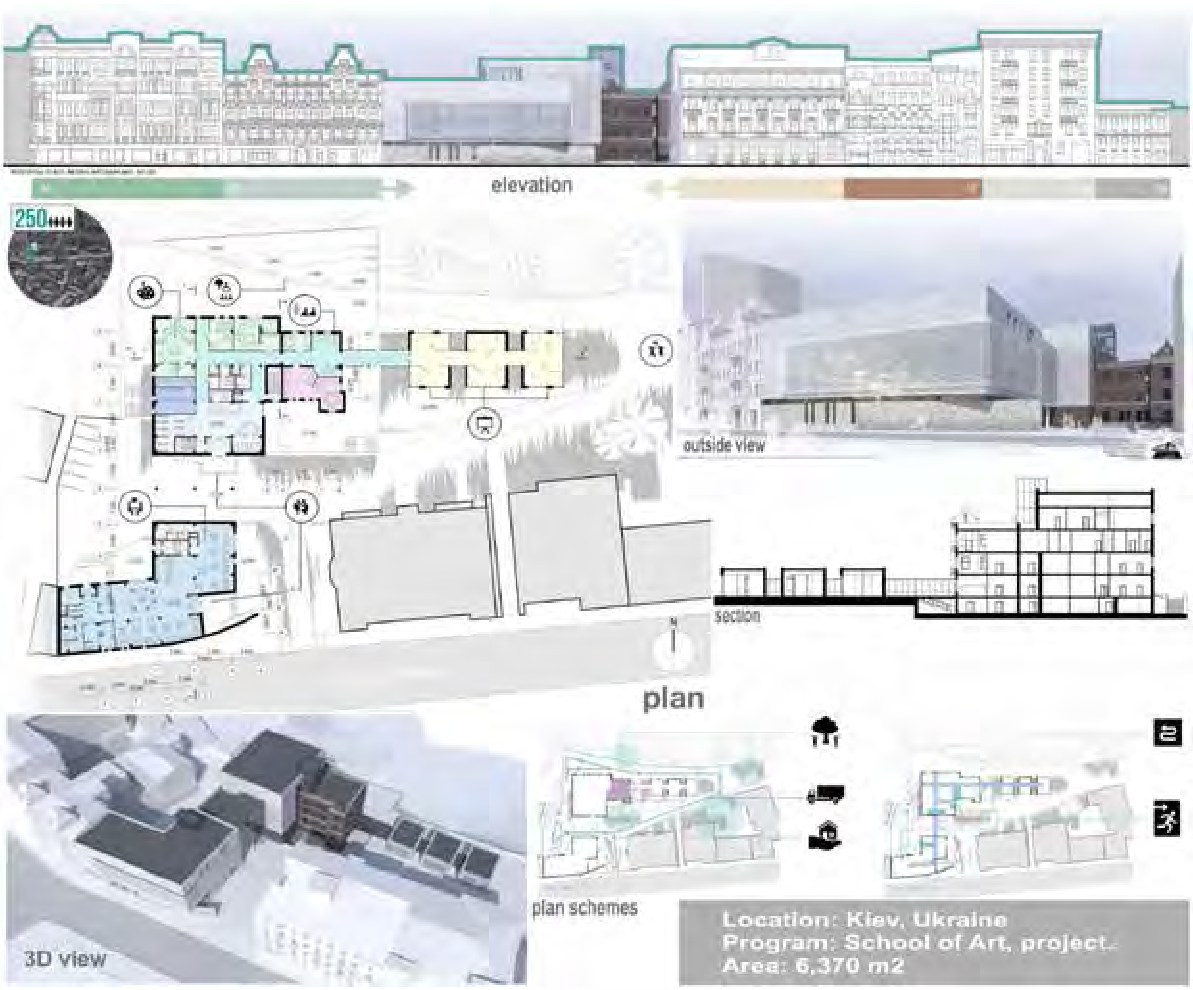


Fig. 6. The diploma project qualification level "master" – Methods of the renovation of children's out-of-school establishments in the conditions of historical development. Complied with student ABS-63 Muleeva V.G. Fragment of the project. The Department of Theory of Architecture of KNUCA, Kyiv, 2016.
Leaders: architect, Ph.D., associate prof. Kravchenko I.L., assistant lecturer Gershuni O.M.
Source: the scheme developed by Iryna L. Kravchenko according to master degree project of Muleeva V.G.

Today, the concept of complex reconstruction, as an attempt to generalize its methods and techniques, is the leading direction in the implementation of the global concept of sustainable development and sustainable human settlements, focused on the preservation and return of restored architecture to the urban environment. In modern architectural theory and practice, methods of carrying out complex reconstruction are divided into two groups: intensive, those that do not need to expand the territory of the city and its parts; and extensive, requiring the expansion of territories. Construction in historical, protected areas requires quite serious adaptation to the site on the one hand and a clear distinction between new and existing houses on the other, since any changes in the historical environment would be noticeable enough for the appearance of the city [20, 21].

Such a tendency as **integration** in the context of the current research is defined in the following aspects:

– The inclusiveness of educational institutions. In Ukraine, the issue of the accessibility of educational institutions for use by persons with special educational needs is still relevant. And although normative documents already exist that oblige designers to create educational institutions accessible to everyone; they basically regulate the sizes of certain architectural elements. But, it is necessary to review in each individual case, the functional planning scheme in such a way as to ensure not only the physical accessibility of persons with special educational needs, but also the full stay of such users in an educational institution. This means that additional facilities should be provided for recreation and rehabilitation activities and for staff who specialize in such problems. Ergonomics issues, in this case, are crucial along with the functional planning component;

– Integration of additional functions and facilities to the existing fund of educational institutions. This position closely intersects with renovation and refunctionalization. There are buildings

Fig. 7. "Raíces Educational Park" from TAP Taller Piloto Arquitectos, Colombia.
Source: the scheme developed by Iryna L. Kravchenko according to [22, 23].

where NFEI successfully operate together with the main purpose; this is a matter of schedule. But, this approach provides the educational needs of small (up to 20 people) and teeny (up to 7 people) user groups at the same time. In the case of an increase in groups, the question arises of the functional reorganization of the institution building. Built-in and attached building blocks for additional educational functions are appeared;

– Integration into the structure of the city, in the existing urban environment. We are talking about the construction of new integrated and specialized institutions, the renovation of existing and the integration of educational centers of a new type in the structure of the city (see Figs. 6 and 7). There are questions about the revision of the standard service radius in order to evenly provide potential users with non-formal education services.

As an illustration of this trend the Raíces Educational Park in Columbia is presented (see Fig. 7). As the architect is saying, the location of the project is in the urban perimeter that makes it a visual icon of the municipality, strengthening the values and traditions supported in an open and collective public space, a scenario of integration, for the creation of an identity and appropriation of it. Within the project the pedagogical and cultural spaces are their most important value in the vacuum that complements them, free and flexible spaces suitable for the meeting, formed from yards and gardens allowing extending their activities to the common space as an area to share. Landscape as primary material is an integral part of spatial construction, taking light and shadow, air, vegetation and the landscape itself which is intrinsic part of the site. The project is in a natural context of transition between urban and rural, this is built from materials and finishes in sight. The Educational Park becomes a space that recognizes its own landscape, showing it with the capacity and the kindness to receive the activities and experiences [22, 23].

The next trend that is being considered is the **optimization** of design decisions. Such a trend is formed under the influence of a socio-economic factor in the aspect of feasibility and economic reasonableness of certain design decisions; technical and political factors in the context of the formation of new types of educational-public buildings; architectural-planning and aesthetic factors. The indicated trend mainly concerns the spatial and structural-functional solutions of the architectural object of the institution of additional education. Due to the increase and complication of relations between premises and groups of premises, the question of the reorganization and optimization of sustainable functional schemes arises. So, for example, the functions of libraries in the structure of educational institutions are expanding and, under the influence of a technical factor, are enriched, reviewed and the médiathèques are formed. The methods of organizing the general educational space as a communicative and educational component are widely used. With the formation of médiathèques and a combination of various groups of educational premises and blocks such space is organise, more often, as the atrium space (see Figs. 4 and 5).

Of course, one cannot say that each tendency mentioned above exists and develops separately from others. All the considered trends are interconnected and complement each other. The author has identified and grouped the development trends of the NFEI architecture in such a way as to show the relationship of the influence of external and internal factors on specific trends and design techniques of non-formal education institutions and, thereby, adjust their educational scenarios.

4. CONCLUSION

Non-formal education (out-of-school education, adult and elderly education, etc.) is, today, one of the decisive mechanisms of the social environment for the full organization of free time, education on interests and needs, creative development and formation of useful skills and competencies, as well as their successful implementation. The design of non-formal education institutions in our time must meet the many requirements and factors, both of external and internal impact.

The most influential category of external factors is the socio-economic, especially in the socio-demographic, socio-professional, socio-territorial aspects. The economic aspect, in addition to the issues of forming the educational material base of educational institutions, is very important in the context of the modern development of the human factor. The technological factor affects both the mechanisms of education and the creation of new types of informative educational space. The political factor in the field of globalization of education, decentralization of power and educational reforms should be reflected in functional scenarios and structural models of non-formal education buildings. The environmental influence factor now obliges all architectural objects, both new buildings and the existing foundation, to meet modern requirements for preserving the environment.

The architectural objects and experimental graduation projects presented for analysis illustrate the influence of external and internal factors on the architecture of non-formal education institutions, as well as the main trends in the development of architecture of educational buildings of a new type.

The main trends in the development of the architecture of non-formal educational institutions, such as cooperation, in-depth specialization, renovation or refunctionalization, integration and optimization were selected. Such trends were highlighted by the author on the basis of the analysis of foreign experience in designing institutions of additional education and according to the results of experimental design at the Department of Architecture Theory of Kyiv National University of Construction and Architecture.

The buildings of the non-formal education institutions that are optimal in terms of the functioning scenario and that are compositionally balanced should contribute to the restoration or acquisition of the necessary competencies, because the space for learning is a component of this learning process and, in our time, already has an informative function.

REFERENCES

[1] Cullen J.: *'Going Lifelong Learning': critical factors for the development of Lifelong Learning Centres Tavistock Institute*, Arcola Research LLP, UK, p. 39.

[2] Bykovskaya O.V.: *Out-of-school education: theoretical and methodological foundations*, EPC ALCON, Kiev 2008, p. 336.

[3] Pavlik N.: *Teoriya i praktyka orhanizatsiyi neformal'noyi osvity molodi* (Theory and practice of organizing non-formal youth education), Publishing House Ivan Franko Zhytomyr State University, 2017, p. 162.

[4] Chahrak N.: *Influence of demographic and socio-economic factors on the development of older adult education in the USA*, Visnyk, Taras Shevchenko National University of Kyiv, "Pedagogy" 2016, 2(4), ISSN 2415–3699, pp. 77–83.

[5] Verbets V.V., Subot O.A., Khristyuk T.A.: *Sociology: Study Guide*, ISBN 978-966-351-222-8, CONDOR, 2009, p. 550.

[6] Smirnov V.: *Navchannya protyahom zhyttya: vid 1920-kh do s'ohodennya* (Life-long learning: from the 1920s to the present), Psychological-pedagogical problems of a rural school: a collection of scientific works of the Pavel Tychyna Uman State Pedagogical University, FOP Zhovtyy O.O., Issue 43, 2012, pp. 342–348.

[7] Jeffery A. Lackney: PhD AIA University of Wisconsin-Madison. 33 Educational Design Principles for Schools and Community Learning Centers, Updated: August, 2007, retrived 28.09.2019 [https://schoolstudio.typepad.com/school_design_studio/33-educational-design-pri.html].

[8] Baker L.: *A History of School Design and its Indoor Environmental Standards*, 1900 to Today. National Clearinghouse for Educational Facilities a program of the National Institute of Building Sciences, 2012, retrived 28.09.2019 [http://www.ncef.org/pubs/greenschoolshistory.pdf].

[9] Habibe Acar. Learning Environments for Children in Outdoor Spaces. Department of Landscape Architecture, Faculty of Forestry, Karadeniz Technical University, 2014, DOI; https://doi.org/10.1016/j.sbspro.2014.05.147, retrived 28.09.2019 [https://www.sciencedirect.com/science/article/pii/S187704281403571X?via%3Dihub#!].

[10] Abyzov V.: *The main factors and conditions of sustainable development. Sastainable design as the paradigm of the space in the XXI century*, Kielce University of Technology, 2016, pp. 19–26.

[11] Abyzov V.: *Modern Conditions and the Impact of the Creation of Architectural Environment*, "Material Science & Engineering – IOP", Vol. 245, World Multidisciplinary Civil Engineering-Architecture-Urban Planning Symposium, WMCAUS, 12–16 June 2017, Prague, Czech Republic, published online 4 November, Bristol 2017, DOI:10.1088/1757-899X/245/8/082050, p. 12.

[12] Kravchenko I.L.: *Impact of socioeconomic factor on architectural formation of buildings for non-formal education in Ukraine*. s p a c e & FORM '39_2019, "Space and Form: Scientific journal of Polish Academy of Sciences and West Pomeranian University of Technology" 2019, No. 39, Szczecin, pp. 45–56, e-ISSN 2391-7725 , ISSN 1895-3247 (Index Copernicus Value), DOI: 10.21005/pif.2019.39.B-02.

[13] Abankina T.V.: *Integratsii i kooperatsii obrazovatel'nykh uchrezhdeniy i organizatsiy sotsial'no-kul'turnoy sfery* (Integration and cooperation of educational institutions and socio-cultural organizations): National Research University Higher School of Economics, Institute of Education, Moscow, Russia 2015, retrieved 03.08.2019 [https://publications.hse.ru/mirror/pubs/share/folder/d1zc5j1zs8/direct/98177364].

[14] Kalinichenko D.R.: *Hlobal'nyy rynok pratsi: suchasni vyklyky dlya rozvytku lyuds'koho kapitalu* (Global labour market: modern challenges for the human capital development), "Scientific Bulletin of the International Humanities University", series: Economics and Management, Vol. 25 (2), Odessa 2017, access mode: http://nbuv.gov.ua/UJRN/Nvmgu_eim_2017_25(2)__15, pp. 60–65.

[15] Sbruyeva A.A.: *Hlobalizatsiya osvity* (Globalization of Education), Encyclopedia of Education/Acad. ped. Sciences of Ukraine; main edit. V.H. Kremen, K.: Yurinkom Inter, 2008, pp. 136–137.

[16] *Byuleten' reyestratsiyi naukovo-doslidnikh ta doslidno-konstruktors' kykh robit (NDR ta DKR) – periodichne vydannya* (Bulletin of research and development (R & D) – periodical), ISSN 2522-4158, Ukrintei, Kiev 2018, 97, p., No. 67.01.18.0768/0117У005420, p. 55.

[17] *Culture Complex De Nieuwe Kolk/De Zwarte Hond; architects*: Jurjen van der Meer, Tjeerd Jellema, retrieved 03.08.2019 [https://www.archdaily.com/514880/culture-complex-de-nieuwe-kolk-de-zwarte-hond].

[18] *Large culture cluster connects old and new, large and small-scale*, retrieved 03.08.2019 [https://www.dezwartehond.nl/en/projecten/cultureel-kwartier-de-nieuwe-kolk].

[19] Merylova I.O.: *Variants of extracuricular educational network's development in Ukraine on the base of world concepts' analysing*, Visnuk Pridneprovs'ka State Academy of Civil Engineering and Architecture, 2015, No. 2 (203), ISSN 2312-2676, pp. 52–63.

[20] Kravchenko I.L., Gershuni O.M., Muleeva V.G.: *Metody renovatsiyi dytyachykh pozashkil'nykh zakladiv ta yikh terytoriy v umovakh istorychnoyi zabudovy* (*Methods of renovation of extracurricular institutions and their territories in the conditions of historical development*), I.L. Kravchenko, O.M. Gershuni, V.G. Muleeva, M*odern problems of architecture and urban planning*, 2016, Vol. 46, access mode: http://nbuv.gov.ua/UJRN/Spam_2016_46_77, pp. 419–423.

[21] Kravchenko I.L., Muleeva V.G.: *Tendentsiyi rozvytku dytyachykh pozashkil'nykh zakladiv* (*Trends of development of children's out-of-school institutions*), I.L. Kravchenko, V.G. Muleeva, *Modern problems of architecture and urban planning*, 2016, Vol. 44, access mode: http://nbuv.gov.ua/UJRN/Spam_2016_44_39, pp. 267–272.

[22] *Raices Educational Park/Taller Piloto Arquitectos*, retrieved 03.08.2019 [https://www.archdaily.com/870235/raices-educational-park-taller-piloto-arquitectos].

[23] *Raices Educational Park, El Peñol, Colombia*, retrieved 03.08.2019 [https://architizer.com/projects/raices-educational-park-4/].

Acknowledgments:

TThe work was financed by the Kiev National University of Construction and Architecture, Architecture, Architectural faculty, Departament of the Architectural Theory

Podziękowania:

Praca była finansowana przez Kijowski Krajowy Uniwersytet Budownictwa i Architektury Wydział Architektoniczny. Wydział Teorii Architektury, Ukraina

LUONG MINH CHINH
Transportation Department, Civil Engineering Faculty,
Thuy Loi University, Hanoi, Vietnam.
e-mail: chinhlm@tlu.edu.vn

Manuscript submitted 2019.09.02 – revised 2019.09.20,
initially accepted for publication 2019.09.23, published in September 2019

ANALYSIS AND ASSESSMENT OF EXISTING STRUCTURAL HEALTH MONITORING SYSTEMS (SHMS) OF CABLE-STAYED BRIDGE IN VIETNAM

ANALIZA I OCENA ISTNIEJĄCYCH SYSTEMÓW MONITOROWANIA STANU STRUKTURALNEGO (SHMS) MOSTU WANTOWEGO W WIETNAMIE

DOI: 10.30540/sae-2019-014

Abstract

Since 2000 when the My Thuan Bridge, the first cable-stayed bridge in Vietnam, was put into operation, and now Vietnam has more than 20 types of cable-stayed bridges constructed throughout the country in the last two decades, which is a significant accomplishment for a developing country like Vietnam. Therefore, the SHM system is gradually being designed and installed for cable stayed bridges to ensure economic exploitation and safety. Due to the limited of financing sources, these systems are very limited, and their quality have a lot to be desired. Also, due to the lack of appropriate classification personnel with experience in the SHM system, these systems encountered a lot of problems. In this article author will deeply analyze the mistakes and problems of these SHM systems, which already exist in Vietnam, to find solutions for the future. Therefore, this will open up new prospects, new challenges and possibilities for the development of these systems in Vietnam in the near future.

Keywords: SHM system, concrete cable-stayed bridge, monitoring system, AE sensors, cracks

Streszczenie

W 2000 roku oddano do użytku most My Thuan, pierwszy most wantowy w Wietnamie. Na chwilę obecną Wietnam ma ponad 20 rodzajów mostów wantowych zbudowanych w całym kraju w ciągu ostatnich dwóch dekad, co jest znaczącym osiągnięciem dla kraju rozwijającego się. W związku z tym system SHM jest stopniowo projektowany i instalowany dla mostów kablowych, aby zapewnić ekonomiczną eksploatację i bezpieczeństwo. Ze względu na ograniczone źródła finansowania systemy te są bardzo ograniczone, a ich jakość pozostawia wiele do życzenia. Ponadto z powodu braku odpowiednio wykwalifikowanego personelu z doświadczeniem w systemie SHM systemy te napotkały wiele problemów. W tym artykule autor dogłębnie przeanalizuje błędy i problemy systemów SHM, które już istnieją w Wietnamie, aby znaleźć rozwiązania na przyszłość. Otworzy to nowe perspektywy, nowe wyzwania i możliwości rozwoju tych systemów w Wietnamie.

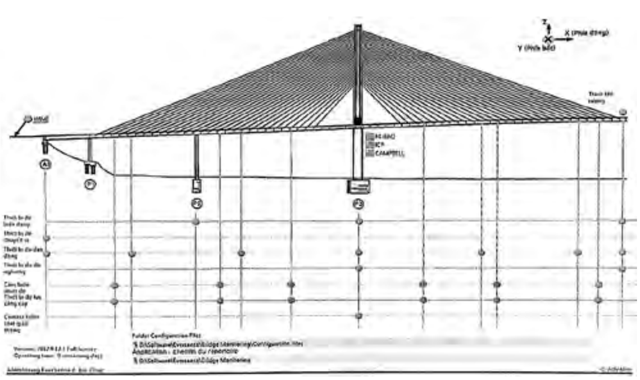
Słowa kluczowe: System SHM, betonowy most wantowy, system monitorowania, czujniki AE, pęknięcia

1. INTRODUCTION

The SHM system for bridges, Andersen et all (2006), has recently been considered for installation on a few cable-stayed bridges in Vietnam due to their sensitivity to the structural load. On April 10, 2012 the Ministry of Transport has sent Official Letter 2727/BGTVT-KCHT, which regulates “Hanging suspension (suspension bridge, cable-stayed bridge) shall be installed monitoring system”, to Directorate of Roads of Vietnam. According to this regulation the special bridge construction (the maximum span length > 150 m high or > 50 m high) is required to have a monitoring system, Chinh (2014).

Bridge projects in Vietnam, which have already installed monitoring systems, are: Bai Chay bridge (Shimizu system during construction and it is no longer in operation, the new system was installing during the exploitation phase by ADVITAM); Rach Mieu Bridge (SHMS built by VSL and TEDI to supervise the construction process), B.H. Huong (2014); The Can Tho Bridge (SHMS by NTT Data -BRIMOS); The Binh Bridge, Hai Phong (VSL and VITEC Engineering); The Rao II Bridge, Hai Phong (MTH and Savcor); The Nhat Tan Bridge (VSL has been installed during the construction phase and the operating station is now operational), Kien Bridge and My Thuan Bridge are being installed, Chinh (2016).

The reality is that the SHM systems installed in Vietnam are quite diverse and currently there are no common regulations, requirements for them from the regulatory authorities. SHM systems are implemented by many different vendors with devices from various suppliers with different number of sensors, quality and cost. The purposes of system design are not consistent. During the exploitation phase of each bridge, the operating unit develops a maintenance manual or maintenance manual, regulations on data, however, the reporting regime is still unclear, lacks of unity and the maintenance requirements are not detailed that leads to difficulties in usage and operation of these new systems, Chinh (2014).



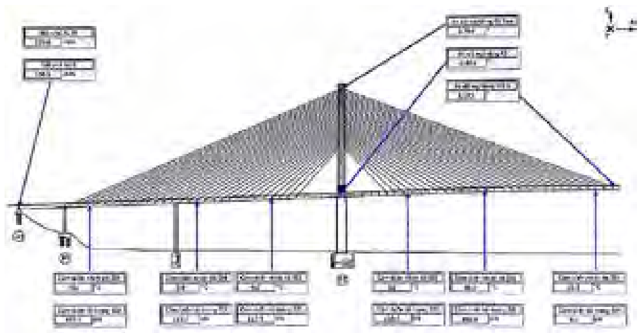


Fig. 1. Main screen of SHMS Bai Chay's Bridge (Advitam)

Table 1. Current devices status of Bai Chay bridge SHM system

No	Device	Quantity	Status	Location
1	Measure the wind	1 set	Normal	On top of P3 pylon (Fig. 2)
2	Weather station	1 set	Normal	Middle of main span (Fig. 2)
3	Traffic flow monitoring camera	4	Normal	P3 pylon
4	Vehicle Weight In Motion system (WIM)	1 set	Normal	10 m from A1 abutment (Fig. 3)
5	Earthquake monitoring	1 set	Normal	A1 abutment
6	Measure the tilt of pylon	1 set	Normal	P3
7	Measure the rotation of girder	2 set	Normal	Segment K_0 at P3
8	Measure the deformation and pylon stress	8 set	Normal	P3 pylon
9	Measure the deformation and stress of girder	12 set	Normal	In the box girder
10	Measure the oscillation of pylon	2 set	Normal	P3
11	Measure the oscillation of girder	2 set	Normal	P3
12	Measure the oscillation of cable	4 set	Normal	Cable (P3 side)
13	Measure the temperature of cable	6 set	Normal	Cable (P3 side)
14	Measure the tension of cable	6 set	Normal	Cable (P3 side)
15	Lightning rod	2 set	Normal	Al, middle of span
16	Backup Power and Data Backup	1 set	Normal	Monitoring station
17	Monitoring station	1	Normal	

2. EXISTING MONITORING SYSTEMS IN VIETNAM

2.1. Bai Chay Bridge SHM system

During the construction of the Bai Chay Bridge, a monitoring system has been installed for the construction phase (by the Contractor Shimizu). However, the system is no longer active (due to a fire inside the bridge box girder). During the construction phase, the data has been sent directly to Research Centre of Shimizu in Japan for analyzing and making necessary adjustments to the construction work. The measurement data during the construction phase is stored by Shimizu and not shared with current management unit.

New monitoring system for the operation phase has been installed by ADVITAM, completed and activated since 2014, but due to limited budget, the system is only installed on one side of the P3 pier. Therefore, the assessment of the overall condition of the structure faces a lot of difficulties. The data collection maintenance is implemented by ADVITAM (during a 5-year warranty, while the other bridges' warranty). However, the company does not have a representative in Vietnam, so the technical support will be a challenge. All system modifications must be made by ADVITAM – this is a restriction that leads to a lack of flexibility of the system.

The bridge management unit concurrently operates the monitoring system, however, it is incapable of analyzing and evaluation of data for assessment and maintenance of the bridge. Also, there is no analysis of the data reported.

There should be a collaboration with experts from universities and research institutes in data analysis and evaluation as well as the possibility of upgrading

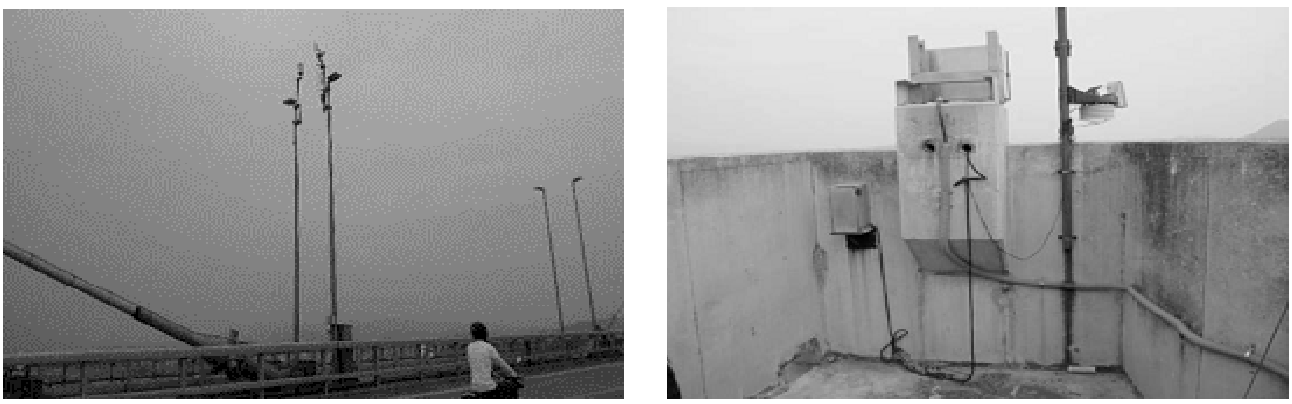


Fig. 2. Weather station install in main desk and on the top of pylon anchor of Bai Chay Bridge

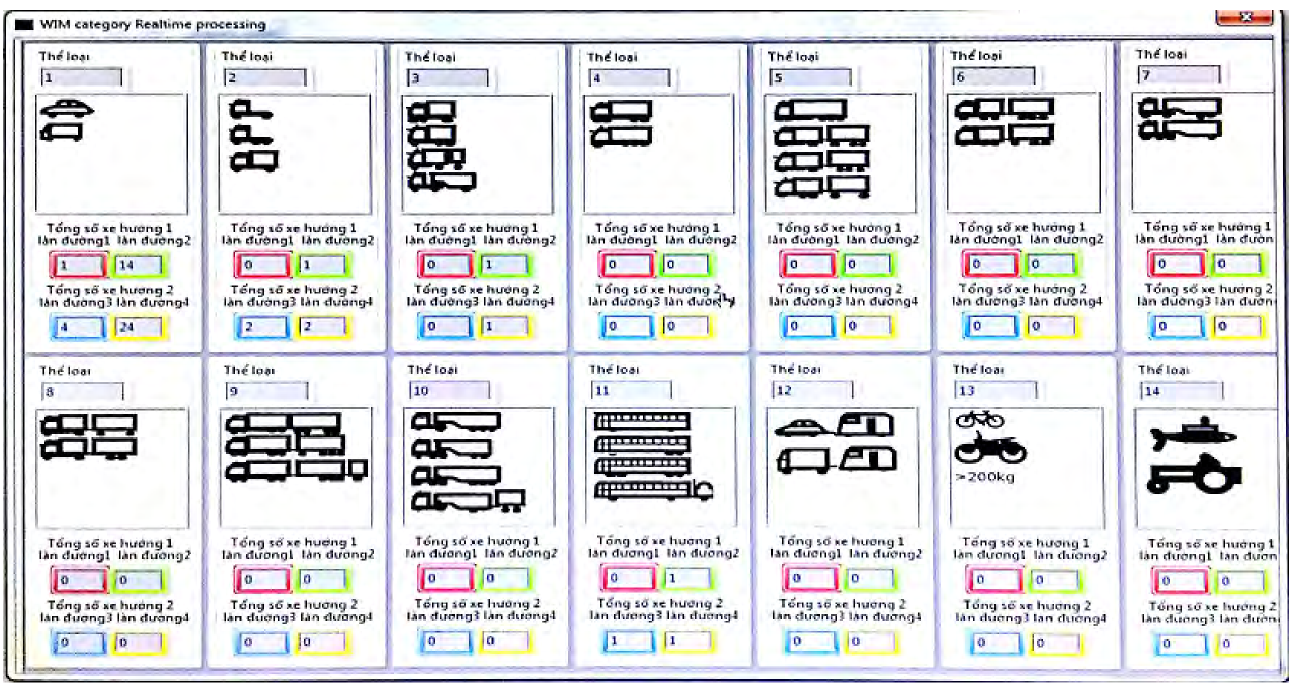


Fig. 3. WIM screen of SHMS Bai Chay's Bridge

existing monitoring systems shall be considered. There should be also a full transfer from ADVITAM for equipment control, software and results of analysis for the data management and analysis unit. Due to the complexity of the Bai Chay bridge structure and the subjects that need frequent monitoring such as bearings displacement, in addition to the regular inspection and monitoring system, other periodical monitoring is required in order to fully assess the current status of the structures.

Fig. 4. Main girder deformation after the ship collision with Binh Bridge during CONSON hurricane

2.2. Binh Bridge SHM system

In 2010, an incident occurred to Binh Bridge in Hai Phong. The CONSON hurricane broke off the anchors of three large ships anchored at Bach Dang Shipyard, about 500m from bridge and they all went downstream, crashing into Binh bridge‘s girder causing damage at main girder (Fig. 4) and two cables, leading to stopping the traffic for vehicles over 3.5 tons until the repair works completed.

In 2012, repair and rehabilitation work was carried out and a monitoring system (phase 1) was established for the purposes: regular monitoring of the operation phase (analysis the behavior of the special structure to assess the behavior under the influence of wind load and weather conditions), support maintenance work for early warning of any abnormal states, as well as to make accurate recommendations on upgrade, maintenance and to recheck design assumptions (Fig. 5).

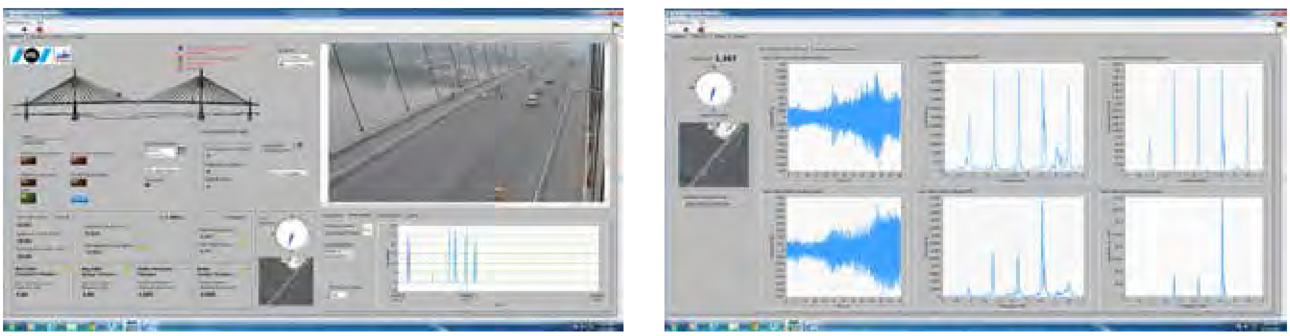


Fig. 5. Main screen of and vibration measurement screen Binh Bridge SHMS by VSL and VITEC

Table 2. Binh Bridge SHMS equipment status

No	Device	Quantity	Status	Note
1	Wind speed and direction	1 set	Normal	Middle of main span
2	Weather station	1 set	Normal	On deck slab near S9
3	Traffic flow monitoring camera	1 set	Normal	S9 pylon
4	Measure the oscillation of girder	1 set	Normal	Middle of main span
5	Measure the oscillation of cable	1 set	Normal	C20
6	Measure the temperature of cable	1 set	Normal	Cable C20
7	Measure the temperature of girder	1 set	Normal	S9 pylon
8	Measure the deformation of girder	1 set	Normal	Middle of main span
9	Monitoring station	1	Normal	Figure 6

Due to limited budget, the minimum option for system has been selected. The basic equipment, that has been installed, will be combined with regular inspection and monitoring on an annual basis to evaluate the current situation of Binh Bridge after rehabilitation. At the time of survey, all devices were working normally (Fig. 6).

Fig. 6. Data equitation using normal PC computer install inside the pylon of Binh Bridge

SHM of Binh Bridge system has some advantages and disadvantages as follows:

- New monitoring system of Binh bridge is very simple with fewer sensors in order to provide some basic warning on tension in the longest cable, girder oscillation, traffic, weather, etc., which do not help in the assessment of the current status of the structures.
- The supplier has an office in Vietnam, which allows a quick technical support; modern equipment and software have a Vietnamese interface with full basic information.
- System management unit is incapable for in-depth analysis of data in order to make assessment and maintenance of the bridge and have no data for analysis reports.
- It should be upgraded to a complete monitoring system that can fully assess the current status of the structure (Level 3, 4).

Due to the complexity of Binh bridge structure, that previously has had an incident and the bridge was once repaired, in addition to the regular inspection and monitoring system, other periodical monitoring is required to fully assess the current status of the structures in order to avoid future incidents.

2.3. Rao Bridge II SHM system

A monitoring system has been installed for Rao Bridge II in Haiphong in 2012, by the end of construction works, for monitoring in operation phase. This is a relatively complete system and if integrated with proper analytical software can help assess the structural status. The cost of the system is lower than some similar systems in Vietnam. But at the time of the survey the system was not active, awaiting repair (Table 3).

Fig. 7. Temperature sensor install on main girder of Rao II Bridge during inspection

Table 3. Current devices status of Rao 2 bridge SHM system

No	Devices	Value	Location	Operating status
1	HI-2	Humidity and temp.	At the abdomen, anchor tunnel	Normal
2	H3-4	Humidity and temp.	Top of the pylon	Normal
3	H5	Humidity and temp.	In the middle of main span	Normal
4	W1	Weather station	Top of the pylon	Normal
5	*D1-D2*	*Transposition*	*Expansion joint*	*No signal*
6	*D3*	*Transposition*	*Top of the pylon*	*No signal*
7	*D4*	*Transposition*	*C15*	*No signal*
8	*Accl*	*Acceleration, 3 dimensions*	*C15*	*No signal*
9	*Acc2*	*Acceleration, 3 dimensions*	*Top of the pylon*	*No signal*
10	*Acc3, Acc4*	*Acceleration, 3 dimensions*	*Stay cable*	*No signal*
11	*Sgl-4*	*Stress measurement*	*Near anchor abutment*	*No signal*
12	*SgS-8*	*Stress measurement*	*Near the second cable*	*No signal*
13	*Sg9-Sgl6*	*Stress measurement*	*Reinforced steel pillar at the elevated pillow position*	*No signal*
14	Cam 1-4	Traffic monitoring	On the pylon	Normal
15	D3R-D4R	Mirrors	Top of the pylon	Normal

In fact, there was a problem and has been fixed in the warranty period covered by foreign supplier. However, at the moment, the warranty period has expired and the support from the supplier has been stop. At the time of inspection, the main sensors did not transmit the signal to the center. The supplier is abroad so should be late in technical support, maintenance; the warranty period is expired and no solution have been taken. System management unit is incapable for in-depth analysis of data in order to make assessment for bridge maintenance and inspection to troubleshoot. It has no data for analysis report. Then the SHM system needs to be repaired and put back into operation as soon as possible.

2.4. Can Tho Bridge SHM system

Can Tho Bridge installed a SHM system – BRIMOS (Fig. 8), Chinh (2014), in operation phase from the end of 2013 with the purposes: to provide data for analysis and to evaluate the structural condition through the behavior of the bridge structure (Fig. 9). Use of monitoring data to manage (control) traffic safety and flow in abnormal conditions as well as provide design check data.

Fig. 8. Main screen of the SMH system of Can Tho Bridge

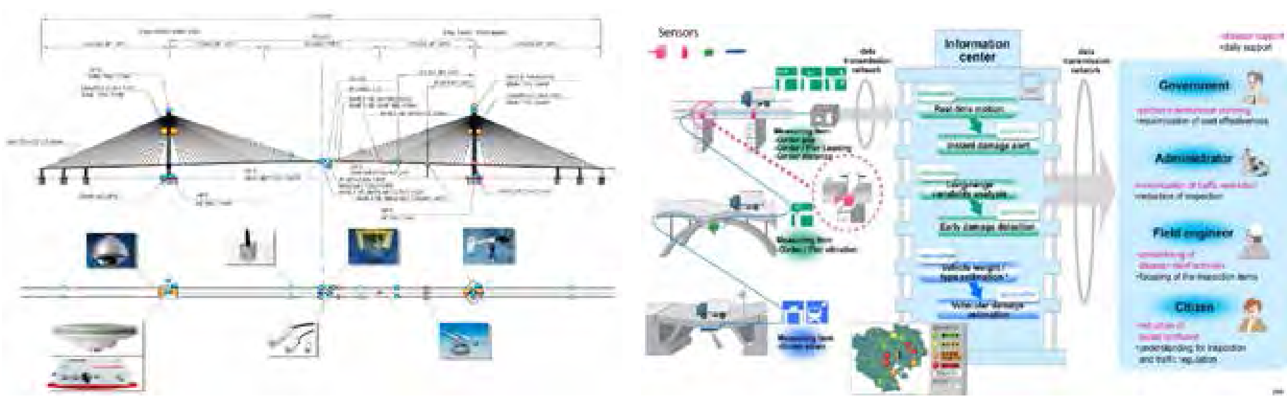


Fig. 9. Schematic of sensors installation of SHMS Can Tho's Bridge (left) and BRIMOS diagram.

Table 4. Can Tho Bridge continuous monitoring equipment

No	Devices	Measuring category	Quantity	Status
1	Temperature	Air temperature	1	Normal
		Steel slab temperature	4	Normal
		Prestressed concrete slab temperature	4	Normal
		South pylon temperature	4	Normal
		Joints temperature	4	Normal
		Monitoring cable temperature	1	Normal
2	Wind speed and direction	Speed / Direction	2	Normal
3	Rain gauge	Rainfall	5	Normal
4	GPS	Different displacements	6	Normal
5	CCTV	Bridge's conditions	4	Normal
6	Handheld accelerometer	Oscillation characteristics	3	Normal
7	Deformation	Deformation of steel slab	8	Normal
8	Fixed accelerometer	Induction oscillator cable	8	Normal

At the time of survey, the monitoring equipment was working normally, transmitting raw data to Can Tho bridge maintenance department. The SHM system send daily reports about its status, but doesn't have detailed analysis of the data due to the incapable of management unit to analyze and evaluate the data. It happened that due to the high frequency of data collection, much higher data leads to memory overflows and the system automatically erase old data, leading to the loss of essential information.

In addition, the system of Can Tho Bridge has some advantages and disadvantages as follows:

- Supplier of the BRIMOS system is NTT DATA, Chinh (2014), a leading IT company in Japan but has not experienced in developing bridge monitoring systems – although BRIMOS is a relatively complete system, but for the first time it has been applied in Vietnam, therefore it has many restrictions. The cost of the system is quite high compared to similar systems in Vietnam.
- GPS data in global coordinates has not yet been transferred to the local coordinates leading to ineffective use, dynamic analysis data has not generated the oscillation frequency of the structure. High frequency of data collection lead to memory overflow.
- The system is installed in the operation phase, so the initial data of status "0" is missing.
- The supplier is abroad so there will be difficulties in technical support, maintenance if any.
- System management unit is incapable for in-depth analysis of data in order to make assessment for bridge maintenance.

To overcome the disadvantages mentioned above, there should be consider the ability to upgrade the software especially for the processing of GPS data to exclude unnecessary duplication of raw data in order to effectively evaluate structure status.

2.5. Nhat Tan Bridge SHM system

Nhat Tan Bridge monitoring system has been installed in construction phase in 2015, which has been handed over and put into operation. The Nhat Tan Bridge is located on the new route from Noi Bai new international airport to downtown in Hanoi, Vietnam. The bridge opened to traffic in January 2015. The main bridge is a 1500 m long, 6-span cable stayed bridge with 8 traffic lanes. This scale of multiple span cable stayed bridge is the first application in Southeast Asia and also very rare type of bridges in the world, K. Matsuno & N. Taki (2014).

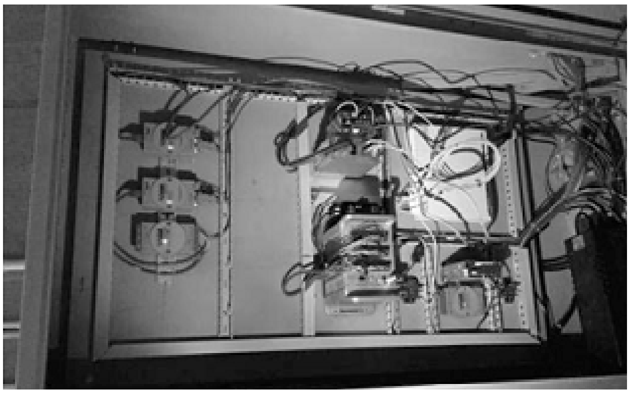


Fig. 10. Installation of SHM system of Nhat Tan Bridge (left) and seismic sensor (right)

Table 5. Basic components of Nhat Tan Bridge SHM system

No.	Device	Quantity	Status
1	System of deformation of main beams and towers	18	Normal
2	Measurement Instrument for the pylon	6	Normal
3	Measurement instrument for cable oscillation	3	Normal
4	Measurement instrument for cable tension	20	Normal
5	Measurement instrument for pylon temperature	40	Normal
6	Measurement instrument for surface temperature	15	Normal
7	Measurement instrument for cable temperature	4	Normal
8	Measurement instrument for deformation of the beam	80	Normal
9	Measurement instrument for ambient temperature	8	Normal
10	Measurement instrument for the wind	1	Normal
11	Measurement instrument for rainfall	1	Normal
12	Measurement instrument for seismic incidents	2	Normal

Nhat Tan Bridge SHM system has been installed in the construction phase, with a large number of sensors, some highly effective measuring cumulative values of construction, such as cable tension and deformation sensors. The system has the most number of sensors. Investment cost is also the highest among systems that have been installed in Vietnam. But adjusting and defining the initial value along with warning thresholds is difficult. At the time of survey, the monitoring equipment was working normally.

System management unit is incapable for in-depth analysis of data in order to make assessment for bridge maintenance and inspection to troubleshoot. There is no data for analysis report.

3. OVERALL ASSESSMENT ON CURRENT SHM SYSTEMS IN VIETNAM

SHM system designed and installed in Vietnam are quite diversified. They were provided by various consultants and came with different quality and cost from many vendors. The determination of the purpose and system building method, analysis and evaluation and use of data are not regulated and specifically guided from state management agencies, so, the comparison and evaluation are relatively complicated. This section provides some basic assessments based on the criteria mentioned above.

Almost all SHM system have ambiguous purpose and the level of monitoring to be achieved has not been determined. The fact that the SHM system, which have been designed and installed in Vietnam, often includes a wide range of categories and various measurement sensors, at very high cost, may be at the maximum price. While to ensure economic and technical efficiency, it is also necessary to determine the appropriate minimum level for each type of bridge according to the decentralization of the project and the current status of the project towards the achievement of a higher level of monitoring. Those systems surveyed are only at level 1, that means, only some basic raw information are provided with some additional warning messages, but warning thresholds are not accurately and clearly defined. But up to now, the targets set for these monitoring systems have not been fully defined. Selection of monitoring system components is relatively diverse, depending on the design unit as there are no general regulations, Chinh (2014).

Table 6. Comparison of SHM system of Bai Chay Bridge and Can Tho bridge (main items)

No	List of equipment	Bai Chay	Can Tho	Remarks
1	Weather, wind measurement station	2 sets	3 sets	
2	Earthquake monitoring	1 set	–	abutment A1 - BC
3	GPS	–	10 sets	
4	Traffic flow monitoring camera	4 pieces	4 pieces	
5	Weighing In Motion system	1 set	–	
6	Tower incline measurement instrument	1 set	GPS	Pier P3 - BC
7	Girder rotary angle measurement instrument	2 sets	GPS	
8	Pylon tower deformation measurement instrument	8 sets	–	
9	Girder deformation measurement instrument	12 sets	8 sets	
10	Girder, tower fluctuation measurement instrument	4 sets	–	
11	Cable fluctuation measurement instrument	4 sets	8 sets	
12	Cable tensioning force measurement instrument	6 sets	–	
12	Manual accelerometer	–	3 sets	
13	Monitoring station	1	1	

Ability of provision of information of SHM system installed is also very diverse. The accuracy of the equipment is also a matter for periodic inspection and calibration. Analysis ability of the current software limits the processing capabilities and further analysis. Many of the data are provided in crude form, especially GPS, oscillation data. Management staff do not have an in-depth knowledge of data analysis and assessment, so the daily reports are mostly just the current status of the operation of the equipment. Initial assessment of the ability to provide information on structural behavior at five levels, Chinh (2015), of monitoring at the bridges with installed SHM system (Table 7).

Table 7. Evaluation of installed SHM system by monitoring level

No	Bridge	SHM System	Current monitoring level	Ability of improvement to achieve level 3, 4
1	Bai Chay	In operation stage	Level 1	Need to complete software and calculation model with an update of monitoring data. The difficulty of this system is that the monitoring system is only installed on tower P3
2	Can Tho	In operation stage	Level 1	Need to complete software and calculation model with an update of monitoring data
3	Binh	In operation stage	Level 1	Need to supplement in second stage
4	Rao II	In construction and operation stage	Level 1	The system has stopped working, need to be rectified
5	Nhat Tan	In construction and operation stage	Level 1	Need to complete software and calculation model with an update of monitoring data

Ability of provision of bridge traffic information – At now the bridge cameras are one of the most effective items in monitoring of traffic flow, accident handling, bridge protection, with sufficient number that can scan throughout the bridge. It is necessary to supplement monitoring radar and traffic count equipment to measurement number, type of vehicles and speed, etc., and combine with WIM that can weigh and determine the load, to restrict overload vehicles.

Ability of provision of information on weather, environmental condition – Information on temperature, humidity, wind direction and wind speed are fully provided. However, the association of these parameters with structural behavior analysis due to the influence of ambient temperature has not been fully conducted.

Warning ability – SHM system installed in Vietnam have set up operational warning systems. However, the determination of values beyond the threshold (warning value) is difficult and in fact, these thresholds are not working effectively. It is possible to apply measurement results obtained during bridge load testing in conjunction with theoretical calculations on the model to establish the required thresholds.

Ability of standardization of structural model – This is the third level that SHM system can reach. In addition, data collection process needs to be long enough (about 3 to 5 years) and in association with experienced experts.

Ability of determination of damaged location, abnormal status of work – These are the highest range of level 4 (state control) and 5 (defect detection) that SHM system can achieve. Achievement of state control is necessary and should set a goal for cable stayed bridge monitoring system. Other applications such as Acoustic Emission (AE) should be applied in detecting damages and damaged locations, especially for reinforced concrete bridges, Chinh et al (2015).

Ability of forecast, assessment of structure working life - This is the highest threshold that the monitoring system can achieve, Friswell et all (1995). The system can forecast working life of the work and many algorithms are now under development in the world to reach this level in order to:

– Support to determine the remaining life of the structure.
– Forecast damage, abnormal status.
– Support to make timely maintenance or preservation.

Ability of combination with other maintenance works – The installed SHM system have initially supported maintenance work. It even reduced many maintenance costs, removed periodical inspection work in many bridge works. However, it should be noted that the SHM system cannot replace the maintenance work, and should be combined with other inspection work to fully assess the current status of the work.

Durability and working life of the system – Sensors have a relatively good working life span (over 5 years), but problems often occur with data transfer connections that results in system malfunction. This is noteworthy as it will affect the continuity and accuracy of the data. The sensors located in concrete have high risk because they cannot be replaced. Particularly, in Rao 2 Bridge, after 2 years of operation, the system has stopped waiting for repair.

Economic criteria – Currently, according to the world's statistics, the current SHM system cost is about 0.3-1.5% of total investment cost. Cost of SHM system in Vietnam are very high. SHM system of Can Tho bridge has a big number of sensors, especially GPS, and the cost of this system can be up to 1 million USD (total investment cost is more than 200 million USD).

4. CONCLUSION

The study has proposed criteria and specification for technical and economic assesment on the basis of Vietnam conditions, including 11 technical criterias and 1 economic criteria. SHM system have been installed on 07 typical cable stayed bridges. SHM system of each bridge has been analyzed to show the advantages and disadvantages, operation situation, practical effect, oustanding works and propose specific rectification solutions to help the management units to learn from experience and have timely rectification.

Cable stayed bridge structure is a completed structure. Its behavior, dependent on frequent and random loads and effects, is very difficult to verify. So, it is more difficult to control by conventional measures. In some cases, the design, construction, quality control work, etc. fully comply with legal documents, technical regulations, relevant standards, etc. but in construction, operation, exploitation process, etc., technical problems, even collapse of works still occurs.

Therefore, the installation of SHM system is necessary to solve the above problems. However, SHM system in Vietnam still has many problems and is not managed consistently. The installation of the SHM system has been individually and spontaneosly carried out in a number of projects, largely dependent on the capital source and subjective opinions of consultants and contractors. The owner and management unit do not have much experience in this sector. The management, analysis, processing and storage of data and parameters collected from monitoring systems in the exploitation process in many works is perplexed, not effective and the number of experts is limited.

REFERENCES

[1] Huong B. H., 2014. *Bố trí thiết bị quan trắc cho cầu dây văng Rạch Miễu – Tạp chí Cầu – Hầm*, TEDI/Bộ GTVT.
[2] Friswell, M.I. and Mottershead, J.E. (1995), Finite Element Model Updating in Structural Dynamics, Kluwer Academic Publishers. ISBN 978-94-015-8508-8.
[3] Nam H., 2018. Hệ quan trắc công trình cầu Cần Thơ - Tạp chí Giao thông vận tải, ISSN: 2354-0818
[4] Andersen J. E., Vesterinen A., 2006. Structural Health Monitoring Systems - First Edition. *COWI – Futurtec* - COWI_ISBN-87-91044-04-9.
[5] Matsuno K. & Taki N., 2014 – *Construction of the Nhat Tan* (Japan Vietnam Friendship Bridge) Superstructure. Bridge and Foundation Engineering Vol.48: 02–12.
[6] Chinh L. M., 2014. BRIMOS – SHM system for cable-stayed Can Tho Bridge, *Inżynieria I Budownictwo – ISSN 0021-0315*. Poland. No 7/2014:.397-400.
[7] Chinh L. M., 2014. Long term structural health monitoring system for cable stayed bridge in Vietnam. *Tạp chí Khoa học kỹ thuật thủy lợi và Môi trường - ISSN: 1859-3941*. No. 44 (3/2014)
[8] Chinh L. M., G. Swit, 2015. Application of the acoustic emission method of identification and location of destructive processes to the monitoring of the technical state of pre-stressed concrete bridges. *Hội nghị khoa học Công nghệ Giao thông vận tải lần thứ III,* năm 2015.
[9] Chinh L. M., Swit G., Adamczak A., Krampikowska A.. 2016. N*hat Tan Bridge – The biggest cable-stayed bridge in Vietnam*. Symposium WMCAUS 2016. Czech. Procedia Engineering 161 (2016): 666 – 673.
[10] Chinh L. M.. Swit G.. 2016. *A Prototype System for Acoustic Emission-Based Structural Health Monitoring of Mỹ Thuận Bridge*. Prognostics & System Health Management Conference—Chengdu (PHM-2016 Chengdu, China).

Acknowledgments:
The work was financed by work University, Hanoi, Vietnam, Transportation Department, Civil Engineering Faculty, Thuy

Podziękowania:
Praca była finansowana przez Uniwersytet, Hanoi, Wietnam, Wydział Transportu, Wydział Inżynierii Lądowej, Thuy

MICHAIL VASILEVICH NEMCHINOV
e-mail: uchsovet@madi.ru
ANNA GENNADIEVNA IVANOVA
e-mail: ag.vasileva@gmail.com
MADI, 64, Leningradsky Prosp., Moscow, 125319, Russia

Manuscript submitted 2018.03.05 – revised 2019.01.02,
initially accepted for publication 2019.09.09, published in September 2019

DECREASING THE HEIGHT OF MOTOR ROAD EMBANKMENTS BY CHANGING THE PRINCIPLE OF WATER FLOW AND SNOW PROTECTION IN THESE CONDITIONS

ZMNIEJSZENIE WYSOKOŚCI NASYPÓW SAMOCHODOWYCH POPRZEZ ZMIANĘ ZASADY PRZEPŁYWU WODY I OCHRONY PRZED ŚNIEGIEM

DOI: 10.30540/sae-2019-015

Abstract

The article puts forward a new type of culverts in roads. Main motive behind the construction of the new type of culverts is presented and examined: considerable height of road-beds at their construction locations and, as a result, unreasonably high road embankments. Snow drifts at roads and possible protection means are also examined. A report on theoretical analysis of the reasons of snow drifts experimental study with road models is included. The model showed low and high drifts blowing at different speeds at roads with and without embankments and with and without a snow-retaining barrier. All experiments were first conducted without cars on the traffic-bearing surface of the road, then with cars. Recommendations regarding road protection against snow are given.

Keywords: water flow, waterless valleys, culvert, speed, flow rate, model, modelling criteria, hydraulic experiment, snow-drift, snow-fall, wind velocity, snow-protection, snow removal, roadway, car, traffic, model, experiment

Streszczenie

Artykuł przedstawia nowy typ przepustów na drogach. Przedstawiono w nim i zbadano główny motyw budowy nowego typu przepustów takie jak: znaczna wysokość koryt w ich miejscach budowy i ich konsekwencja w świetle nieuzasadnionych wysokich nasypów drogowych. Badane zostały również zaspy śniegu na drogach i możliwe środki ochrony. Uwzględniono raport z teoretycznej analizy przyczyn na podstawie eksperymentalnych badań nad zaspami śnieżnymi, wykorzystując modele drogowe. Niniejszy model pokazał niskie i wysokie zaspy z uwzględnieniem wiatrów wiejących z różnymi prędkościami na drogach z nasypami i barierami przeciwśnieżnymi oraz przypadek bez nich. Wszystkie eksperymenty przeprowadzono najpierw bez samochodów na nawierzchni drogowej, a następnie z samochodami. Przedstawiono zalecenia dotyczące ochrony dróg przed śniegiem.

Słowa kluczowe: przepływ wody, doliny bezwodne, przepust, prędkość, prędkość przepływu, model, kryteria modelowania, eksperyment hydrauliczny, dryf śniegu, opad śniegu, prędkość wiatru, ochrona przed śniegiem, odśnieżanie, jezdnia, samochód, ruch drogowy, model, eksperyment

1. INTRODUCTION

Lack of soil for the construction of road structures and for construction of road-beds has become a major (and in many cases primary) concern during the construction of new motorways. It causes long delays in the construction of new roads. Sometimes these delays are measured in years. Codes and standards have long since excluded recommendations concerning construction of road-beds with zero embankments. Highway engineer's handbook mentions this type of road profile only ones and gives no further description of it later on [1-4].

In this study we look at the task of decreasing the height of embankment by refining small culvert structures. This article will examine, first, changing approaches to hydraulic engineering, and second – changes in snow drifts related to the decrease of the embankment height [5-8].

Crossing over small streams and dry gaps (seasonal streams) requires construction of small culverts – small bridges, pipe-culvers and other types of road hydraulic structures. Their number is high not only on rough terrain but even on level grounds – there is at least one of them per each road kilometre. Construction of small culverts is closely connected to the problems related to the construction of road-beds of motorways, especially with the automatization of the design process, when it is during the design process that reference points of longitudinal road profile are determined that are later used to set up or create the longitudinal profile of the road. Project line determines elevation of the road-bed and, therefore, the demand for soil for its construction and, in the long run, construction cost. Road-bed elevations over small culverts constitute some of these reference points. These elevations are sums of the stream bed elevation, height of the structure (culvert pipe) and height of the soil cover above the pipe. Standard minimum ID is 1m, OD – 1.2...1.3 m, and soil cover above the pipe is at least 0.5 m thick (Fig. 1) [9-10].

Fig. 1. Road-bed and pipe culvert at km 122+629 of Moscow-Voronezh motorway. Pipe diameter 0.75 m

This embankment shall therefore be at least 2 m high. As a result the road-bed is formed on an embankment that is unreasonably high. Construction of motorways along the whole of their length on embankments, i.e. as a systematic construction method at level terrains, causes substantial damage: it cuts territories into separate isolated areas; damages hydraulic geology of the adjacent territory. It also affects flora and fauna; requires an enormous about of soil and installation of numerous soil banks. Ways shall be sought to decrease the height of embankments at level terrains. One of the solutions is to decrease construction height of road-bed at small culverts [11-13].

On the other hand as height of the embankment is decreased the snowdrift problem becomes more prominent. Though the climate is changing, its winter meteorological phenomena remain the same. So that the main reason of snow drifts on roads – snow fall from the clouds (snowfalls) and relocation of snow onto the roads (blizzards) remain. Theoretical base for the protection of roads against snow drifts is strong and, what is more important, has been tested in practice on motorways for decades [14-16].

Everything stays the same but for one thing. It was established that examination of snow protection measures, development of snow protection and snow removal systems, its testing were carried out during the time when the traffic load was very low. In the past, there were very few cars on the roads, while nowadays the traffic is dense, both in winter and in summer. The traffic effectively serves as an barrier preventing snow transport that did not exist before. As a result, aerodynamics of snow flow over the road-bed has changed drastically – from structure well streamed by the air flow it has transformed into a poorly streamed structure. Road bearing surface now bears a snow-retaining barrier – a fence – made up of cars that retain snow and air flow which leads to snow deposition.

2. THEORETICAL ANALYSIS OF THE WATER FLOW

Culverts construction practices have adopted a principle of narrowing the potential floodwater flow [14]. It is based on the fact that the opening of the culvert is narrower than the width of the potential water flow. The smaller culvert opening (1 m diameter as a rule) results in an accumulation of water in front of it and flooding of a considerable part of waterbed. With a considerable embankment height. This almost inevitably leads to local washout of the downstream channel.

Water flow widening before the motorway road-bed means that a small culvert shall be constructed with an opening as wide as the water flow width. With discharge capacity at the same level the height of the opening can be lowered, as can the height of the embankment. We shall call it flattened structure.

The main advantage of building such structure is that the reference elevation for the design of longitudinal profile can be lowered and, as a result, the road-bed height may decrease so much that the road can be constructed at ‘elevation zero’ (see Table 1).

Table 1. Possible change in height of the embankment and amount of imported soil for the construction of embankment of Moscow - St. Petersburg road and Central Ring Road around Moscow after construction of flattened culverts.

Road parameters and construction characteristics	Moscow - St. Petersburg motorway				Central Ring Road km 7–10, 31–35	
	km 549 – 556,5		km 562 – 572			
	Project	Proposed	Project	Proposed	Project	Proposed
Length of embankments, m	7 500	5 175	10 000	7 385	4 849	3 860
Length of excavations, m	0	2 325	0	2 615	2 151	3 140
Average position point of the top of the traffic bearing surface, m	2.61	0.07	2.47	0.51	1.01	0.64
Average position point of the top of the road-bed, m	1.67	- 0.87	1.53	- 0.43	- 0.03	- 0.37
Road mat thickness, m	0.94	0.94	0.94	0.94	1.04	1.04
Average depth of the excavation, m	–	0.16	–	0.11	1.99	1.90
Amount of soil for embankment, thousands of m^3	438.37	154.39	612.09	195.43	736.88	438.64
Amount of soil from excavations, thousands of m^3	0	161.780	0	204.18	193.036	266.16
Amount of imported soil, thousands of m^3	438.38	0	612.1	0	543.85	172.48
Soil removed from construction site, thousands of m^3	0	7.39	0	8.75	0	0
Number of zero elevations, pcs.	0	19	0	30	12	15
Number of culverts, pcs.	7	2	4	3	9	6
Length of roadside ditches, m	7 500	9 462	7 500	9 462	5 462	8 650

Note. The number of culverts has been decreased because of a change in the organization of surface runoff drain.

Reverse is also possible – "the road" may serve as a supplier of soil (from excavations and draining ditches) for the construction of embankments as the roads cross deep stream beds and other low terrain areas.

Modification of the construction principle of small culverts calls for certain changes in construction related to the hydraulics of the water flow. In the examined case intake stream bed coming up to the road-bed required widening the culvert to the required size. Decreasing the height of the culvert is limited by the requirement to clean it to remove water flow sediments. Small longitudinal slopes of shallow stream beds together with vegetation slow down the water flow and, consequently, the water flow carrying capacity. Coarse contaminants in accordance with operation (maintenance) rules for small culverts shall be removed by the road services. Hence, the minimum height of a culver can be limited to 0.3...0.4 m.

Flattened culvert can operate (preferably) without pressure or pressurized. The latter alternative is worse as it will create additional pressure and flood the road-bed and increase the speed of water at the exit of the structure.

As the stream bed widens so does the water flow (it spreads), its depth and flow speed decrease as the flow rate becomes constant (see Fig. 2).

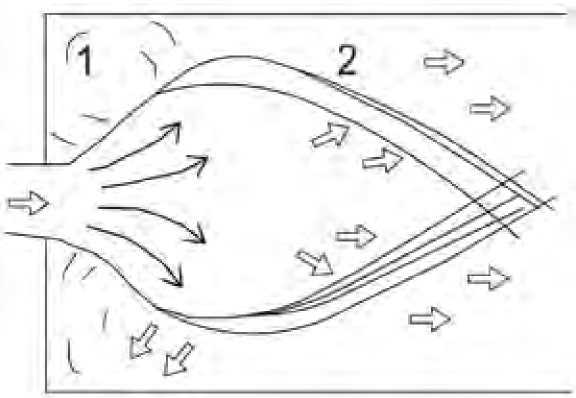


Fig. 2. Spread of a turbulent water flow in wide river beds: 1 – eddy current; 2 – angled hydraulic jump waves.

It is achievable that water flow speed becomes so low that it does not erode soil. The stream bed widening area shall be long enough to allow for a smooth widening of the water flow till it reaches the spreading width.

With a high accuracy at the first approximation for the cross-section of the water flow coming from the natural stream bed to the widening area specific water flow velocity E can be calculated using a formula (1):

$$E = \beta \cdot h_{out} + \frac{\alpha \cdot V_{out}^2}{2g} \qquad (1)$$

where: β – potential energy coefficient taking into account non-hydrostatic distribution of pressure at the exit section; h_{out}, V_{out} –depth and speed of water flow at the exit section, respectively. If the shape of the cross section at the stream bed part of the lowland is close to a circle (like that of a pipe) β coefficient during non-pressurized flow and filling of the stream bed $h_0/(D$ = [0.1…0.5)] is equal to [0.5…0.6] (D – diameter of an equivalent pipe, h_0 – depth of the water flow at the stream bed of the lowland).

As with small bridges the depth of a flow at the outlet section is calculated using Bernoulli's equation. Numerous studies show that before the water flow leaves the lowland and enters its widened part an area forms where the water surface level is lower lout = [3…4] × h_{out}.

For this area, disregarding (due to their small values) the changes in slope and friction forces the following equation can be made (2):

$$h_1 + \frac{\alpha \cdot V_1^2}{2g} = \beta \cdot h_{out} + \frac{\alpha \cdot V_{out}^2}{2g} \qquad (2)$$

Table 2. Coordinates of the flow lines and lines of the same depth () for the graph in Fig. 4.

Q,%	Coordinates	Lines of the same depth								
		0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
0	x/b Fr_0	0.050	0.150	0.280	0.400	0.500	0.600	0.730	0.860	0.110
	y/b	0.503	0.510	0.530	0.565	0.620	0.675	0.760	0.870	0.100
10	x/b Fr_0	0.165	0.205	0.460	0.610	0.790	1.000	1.210	1.660	2.770
	y/b	0.405	0.420	0.450	0.500	0.575	0.690	0.820	1.110	1.980
20	x/d Fr_0	0.270	0.430	0.610	0.780	0.970	1.220	1.590	2.140	3.790
	y/b	0.310	0.330	0.360	0.410	0.480	0.580	0.750	1.020	1.840
30	x/b Fr_0	0.370	0.530	0.710	0.880	1.060	1.360	1.800	2.460	4.370
	y/b	0.210	0.230	0.250	0.290	0.350	0.440	0.560	0.770	1.360
40	x/b Fr_0	0.450	0.590	0.750	0.920	1.120	1.430	1.910	2.690	4.770
	y/b	0.115	0.125	0.140	0.160	0.190	0.230	0.300	0.410	0.760
50	x/b Fr_0	0.480	0.610	0.770	0.940	1.130	1.450	1.950	2.760	4.940
	y/b	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Note. $Fr_{out} = Fr_0$; b – depth of the flow (stream bed) as it enters the widening area; x – distance along the water flow, y – distance across the water flow.

After all modifications have been made we get the following final design formula (3):

$$\eta = \frac{\left[1 - \frac{\Pi_{k1} \cdot \left(1 - \frac{w_1^2}{w_{out}^2}\right)}{2}\right]}{\beta} \qquad (3)$$

where: $\Pi_{k1} = \alpha \times V^2 1 \div g \times h$; ratio w_{out}^2/w_1^2 is substituted with ratio $w_1^2/w_t^2 = w_{out}^2/v_1^2 \times \eta = h_{out}/h_1$, W – area of the cross-section of the flow in corresponding cross-sections. b – values h_1 and Π_{k1} at lowland slopes $i_0 > i_k$ for the considered case are equal: $h_1 = \underline{h}_0$; $\Pi k_0 = Fr^2$ (taking into account large length of the lowland), $Fr = V^2/2g$ – Froude number for section1.

During calculation of the flow spreading I.A. Sherenkov's graph is used. We shall calculate $Fr_{out} = V_{out}/\sqrt{g} \times h_{out}$ and for flow axis (axis X) using Table 2 we find ratio for flow depths at different distances from the outlet cross-section.

The provided data illustrates that hydraulic calculation can be used to project the required conditions of water flow as it approaches the culvert.

At the outlet of the structure the width of the stream is the same as the width of the opening. Water flow speed of a single-span structure is almost the same as the water flow speed at the inlet point. This speed has decreased due to the widening of the stream. Thus, the stream does not have to be further spread. If required and if the soil of the stream bed fits for the purpose the speed at the outlet of the structure may be lowered down to one that does not erode the soil of the stream bed.

2.1. Experimental study results

To assess the spread of the water flow visually a hydraulic experiment was conducted at an inlet part of the stream bed. The scale of geometric simulation is 1:2. At the model the width of the inlet stream bed is 0.60 m; water flow speed at the outlet cross-section is 0.860 m/s; water flow rate is 0.01548 m^3/s. With Froude scaling this corresponds to the actual flow 1.2 m wide at the outlet cross-section with water flow speed of 1.216 m/s $Vn^2 = Vm^2 \times hn/hm$ and flow rate of 1.459 m^3/s.

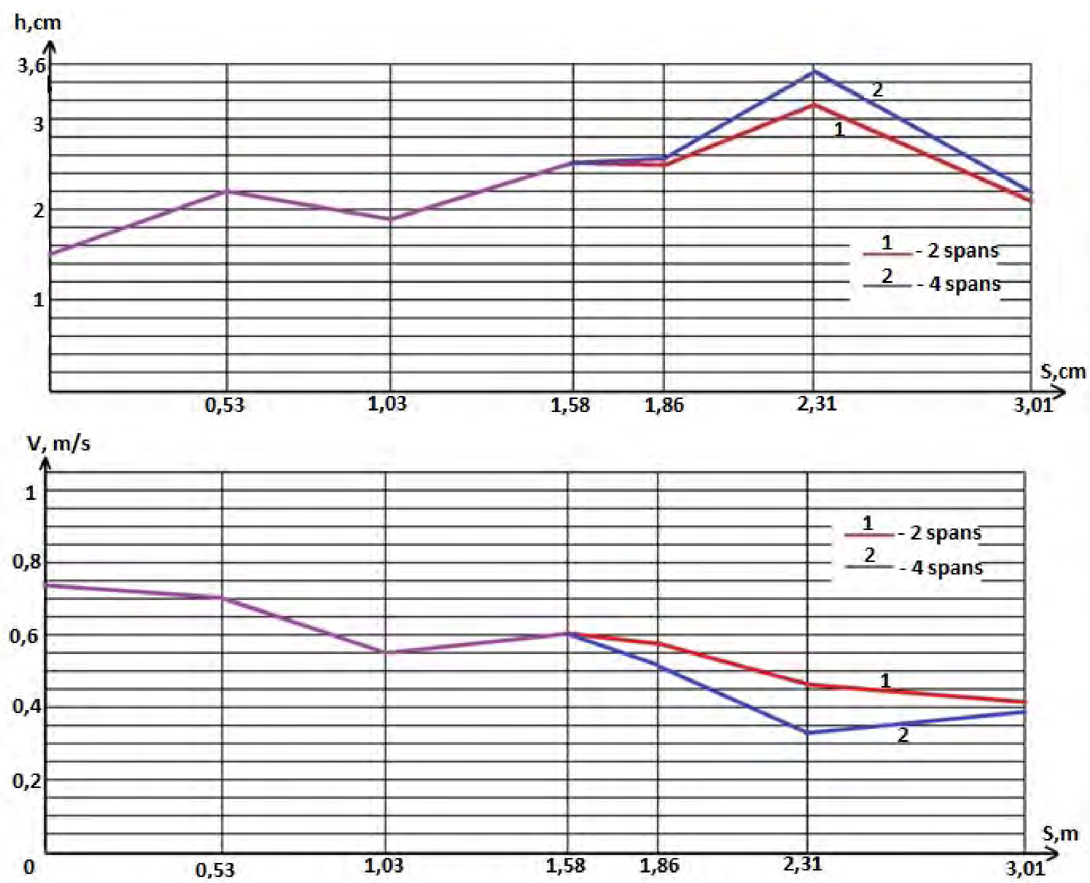


Fig. 3. Graphs showing change in the level of open water surface and water flow along the flow axis at its widening area

The model length of the stream widening area (lp) was 1.05 m which corresponds to the actual length of 2.10 m. Therefore, in accordance with the diagrams (see Fig. 3) the length of the stream bed widening are at the inlet of small culvert I shall amount at least to the sum of lp + lк.

2.2. Partial consclusions

Theoretical and experimental studies lead us to the following conclusions:

- Construction of flattened small culverts by decreasing their construction height allows for a considerable (sometimes, total) decrease the demand for imported soil for the construction of road-bed, which makes it cheaper and easier (organization-wise) to construction a motorway.
- A new method of construction of small culverts have been proposed that is based on widening the streambed of the water flow as it approaches the culvert (instead of narrowing it). This method required individual approach and increasing hydraulic calculation of water flow parameters for each individual case, more serious approach to the collection of hydraulic data for the formation of water flow during floods period brought about by the necessity to prepare (widen) the intake channel.
- Adoption of flattened culverts in designs requires a review of the road runoff drainage. Standard construction of side catch water drains shall be supplemented with a development of a spatial system of intake and removal of runoff from the road-bed of motorways. During the development of such drainage system the area adjacent to the road shall be examined and watercourses, waterless valleys, lowland areas shall be identified where during flood periods the runoff may be diverted to to avoid building culverts at flat land.

Small flattened culvert with proper design can be built without reinforcing outlet stream bed (but for the natural or planted vegetation) – if by widening the inlet (and, therefore, outlet) stream bed water flow speed can be decreased to the level wen it no longer erodes the soil of the stream bed. Outlet stream bed can also be reinforced with rock fill.

3. SNOW DRIFTS PHENOMENON INVESTIGATION

Russia is a northern country with long winters, low below-zero temperatures, harsh winds, snow falls and snowstorms. Hence, it has a vast experience successfully preventing and removing snow drifts from auto roads. In recent years, however, it has become clear that all this is no longer enough: the main auto roads equipped with powerful snow removing systems and protection means against snow drifts witness prolonged many kilometres long traffic jams caused by snow drifts on the traffic bearing part of auto roads. This means that old, tried-and-true methods and ways do not suffice any more. Why is that?

3.1. Methods of investigation

In order to answer this question we need to analyse a lot of different factors. A number of methods has been used – both theoretical and experimental – to tackle different aspects of the problem, to collect, to generalize and to analyse the knowledge and experience base of road winter maintenance. Facts about winter meteorological natural phenomena – snow-falls, snow-storms, snow physical properties in air and on the road surface, with traffic, have been reaffirmed. It was collected known information about air dynamics of road-bed – in embankment, pocket, at ground level. Then it was established how roads behave with the snow-storm protection – snow protective facilities: snow cover, hurdles, fences, windrows, snow trenches and guard walls. Snow removing methods were also studied. Air dynamic experiments were made using models.

Model analysis criteria: Newton's condition (Ne): $F_n\, ln / M_n\, V_{n2} = F_m\, lm / M_m\, V_m\, V_{m2}$; Froude number (*Fr*): $V_{n2}/g\, l_n = V_{m2}/g\, l_m$; Reynolds number: $ln\, V_n / v_n = l_m\, V_m / v_m$. Strouhal number: $\mathrm{ln} / (V_n\, t_n) = lm / (V_m\, t_m)$ and Euler number: $p_n/\rho_n\, V_{n2} = p_m/\rho_m\, V_{m2}$ have been analyzed. Froude (*Fr*) and Reynolds (*Re*) numbers were chosen as primary ones. Based on the examination of the criteria geometrical (αl) ($\alpha v = \alpha l\ {}^1/_2$) model analysis scale has been chosen. The issue of air flow solid discharge model analysis has also been reviewed based on the drifts model analysis: $Re = V/W_o$ = idem, V_2/gd = idem, Re > Red. Saturation (*S*) of the air flow with solid particles was evaluated using the following equation $S = 0.009\ (V_{kp}/W_o)6\ (d/D)3.5$. (Where: M = mass, v – viscosity, ρ – density, p – pressure drop, t – time, $V_{кр}$ – speed required to transport a set number of suspended-state solid particles of a certain grain-size composition, W_o – settling velocity of solid particles).

Road-bed (embankment height), cars and air flow (turbulence, speed) were used for model analysis. Deposition of drifts from air flow has been evaluated qualitatively.

3.2. Study results. Theoretical analysis

A lot of information has been collected that cannot be covered by a short study like this one. For that reason a monograph Snowdrifts on the Roads and Snowdrift-Protection under Modern Conditions has been compiled and is pending to be published at the moment.

The study showed that the main factors causing snowdrifts remain the same, although the climate is gradually changing its winter meteorological phenomena don't. That is why the main cause of snowdrifts on roads is snowfalls and snow relocation to the roads (during snowstorms). Snowdrift protection measures are very well studied in theory and, more importantly, have been tested for decades in practice – on the roads.

All but one thing stays the same: it has been established that snow protection issues, development of snow-protection and snow-disposal systems and their testing took place when the road traffic was very low. In the past roads carried very few cars, while nowadays they are subject to heavy traffic flows both in winter and in summer seasons. A structure preventing snow from drifting over the road appeared in the middle of the roads, that hadn't been there before. As a result the air dynamics of the air flow above the body of the road has changed drastically - roads that used to be a structure easily bypassed by the air flow now cannot be bypassed. Cars form a snow retaining barrier that detains wind and snow flow and causes snow falls. Snow ploughs mainly clean the motorways and sides of the roads from snow that falls from the skies. The snow that is transferred to roads during snowstorms accumulates because of traffic flow. The time for snow removal has been cut substantially as there are hardly any breaks in traffic flow apart from night time. Traditional snow cleaning process requires a group of snow ploughs. Their operating speed is not very high, and is considerably lower than the speed of cars. This holds back the traffic and creates long rows of cars. Hence, snow cleaning works obstruct the movement of the cars. As a rule, snow-cleaning operations are conducted at 30…40 km/h. Snow is not thrown far from the traffic-bearing surface of the road, instead it is, at best, pushed next to the edge of the road-bed like a dam that also contributes to the retention of snow during snowstorms.

3.3. Experimental study

Motorway road-bed has been analysed using a 1:60 scale model set at ground level and on an embankment (model – cm, actual height – 1.8m) and operating during ground blizzard with wind flow speed ranging from 5.0 to 1.3 m/s (actual speed 38.7… 10.1 km/h) with and without a snow barrier to the windward side of the road. Traffic-bearing surface of the road has two traffic lanes where: cars are present; cars are present and are moving in one row (take up one lane), are present and are moving in two rows (take up two lanes). A snow imitating material was added to the air flow.

For the study results for models see Figures 4-8.

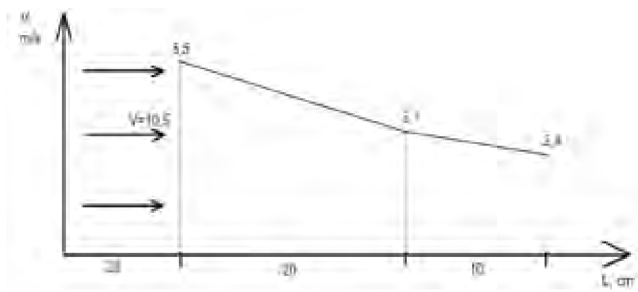


Fig. 4. Graphs reflecting change in speed of the air flow over the road-bed with no cars on the traffic-bearing surface: a) without snow shield; b) with a snow shield; • - Speed measuring point.

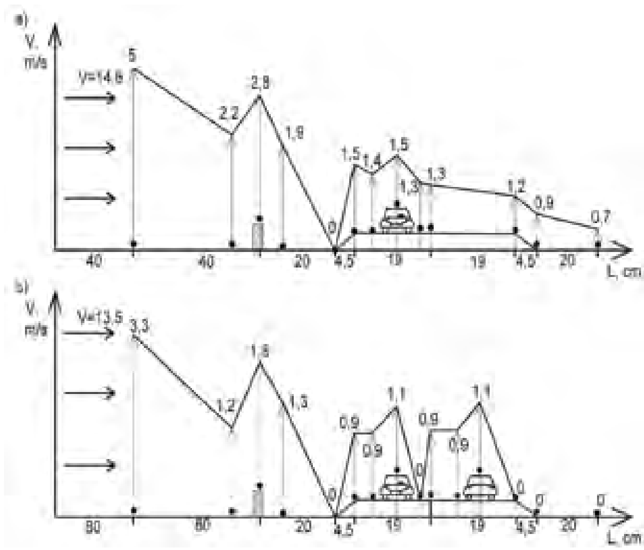


Fig. 5. Graphs reflecting change in speed of the air flow over the road embankment with a snow shield and cars moving on the traffic-bearing surface with: a) one-lane traffic; b) two-lane traffic; • - Speed measuring point.

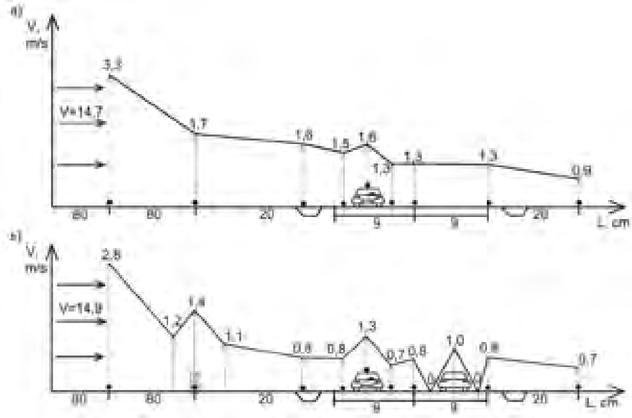


Fig. 6. Graphs reflecting change in speed of the air flow over the road with traffic-bearing surface at ground level with: a) one-lane traffic, no snow shield; b) two-lane traffic, with a snow shield; • - Speed measuring point.

Fig. 7. Deposition of solid particles from the air flow on the model of the road with traffic-bearing surface on an embankment. One-lane traffic.

Fig. 8. Deposition of solid particles from the air flow on the model of the road with traffic-bearing surface on an embankment. Two-lane traffic.

3.4. Partial Conclusions

Changes in the air speed over traffic-bearing surface of the road showed that in ground blizzard (air flow height up to 2…3 m) car flow on the surface of the road contributes to blizzard drifts and therefore – formation of snow drifts. Regardless whether there is a snow-retaining barrier in front of the road or not. These natural phenomena do not change regardless of the climate changes, they shall be treated as a fact. Busy traffic on the roads that was formed during the motorization of society and that is not expected to decrease in the foreseeable future shall also be treated as a fact. These facts make winter maintenance of motorways an extremely important issue. The most important being protection of traffic bearing surface of the road against snow sedimentation.

4. RECOMMENDATIONS

Prevention of blizzard depositions on the existing roads may be ensured by enhancing the protection system – by installing blow-over fences at the edge of the roads or at the top of the slope (close to the sod line) of the road-bed or by construction of permanent or temporary (easily assembled, transparent materials use is possible) smoothly streamed snow protection galleries. New motorways shall be constructed with embedded snow protection, i.e. so that blizzard depositions cannot form on the traffic bearing surface of the road.

New snow removal conditions also require technical improvement of snowploughs. Snow ploughs shall be equipped with blades with configuration that contributes to the formation of snow vortexes to throw snow as far away as possible, for example, by changing the shape of the blade and equipping the snow plough with a fan or air cannon. During snowfalls and blizzards with high wind speed it is feasible to change the principle of snow removal with a snow plough – instead of moving and throwing it away a blow-away principle may be employed – strong airstream may be used – like a jet one, but with a low heating temperature (or without any heating). The Russian Federation has a certain experience in using aeroplane jet engines past their code-specified expiry date for removing snow and ice from roads.

An important aspect of snow protection (as part of winter roads maintenance) in introduction of a new traffic control regime: control of speed and overtaking, prohibition (temporary restriction) of driving during snowfalls and blizzards. This will require cooperation with neighbouring road operation institutions. The main thing during emergency situations is to inform and warn drivers about a high risk of snow jams and their effect on cars movement and control (regimes and speed).

REFERENCE

[1] Nemchinov M.V., Vasilyeva A.G.: *Ways to reduce the excavations in motor roads construction*, Moscow State University of Road Traffic (MADI) Herald, 2016, 2 (45), pp. 62–70.

[2] Nemchinov M.V.: *Protection of small-scale artificial structures from local erosion. Scientific and technical report*, No. 745, M.: MADI, 1964, p. 115.

[3] Bolshakov V.A.: *Hydrotechnical structures at motor roads*, M.: Transport, 1965, p. 320.

[4] Duncan C.S.: *Revenue For Highway Construction And Maintenance. Annals of the American Academy of Political and Social Science*, 1934, t. 171, No. 1, pp. 244–252.

[5] Kolisoja P., Kalliainen A.: *Modelling of Plastic Culvert and Road Embankment Interaction in 3D*, "Procedia Engineering" 2016, Vol. 143, pp. 427–434.

[6] Perminov A.N., Safonov I.P., Perminov N.A.: *Innovtive Technology for Repair of Culverts in Conditions of Constant Intense Water Flow*, "Procedia Engineering" 2017, Vol. 189, pp. 505–510.

[7] Villalva P., Reto D., Santos-Reis M., Revilla E., Grilo C.: *Do dry ledges reduce the barrier effect of roads?* "Ecological Engineering", Vol. 57, August 2013, pp. 143–148.

[8] Fragkakis N., Marinelli M., Lambropoulos S.: *Preliminary Cost Estimate Model for Culverts*, "Procedia Engineering" 2015, Vol. 123, pp. 153–161.

[9] Kopanev I.D.: *Snow cover study methods*, L.: Hydrometeorological publishing, 1971.

[10] Byalobzhevsky G.V., Ivanov A.N., Shalman D.A.: *Snow removal from motor roads*. M.: Transport, 1972.

[11] Gedotov G.A., Pospelov P.I.: S*urvey and design of motor roads*, Book 1, M.: Vyshaya Shkola, 2009.

[12] D*esigning motor roads. Highway engineer's handbook*, M.: Transport, 1989.

[13] *Highway engineer's handbook. Maintenance and repairs of motor roads*, M.: Transport, 1974.

[14] *Motor roads maintenance in winter time*, ed. by A.K. Dyunin, M.: Transport, 1983.

[15] Nekrasov V.K., Aliev R.M.: *Motor roads maintenance*, M.: Vyshaya Shkola publishing, 1983.

[16] Nekrasov V.K.: *Motor roads usage*, M.: Vyshaya Shkola, 1970.

Acknowledgments:

The work was financed by Moscow automobile and road construction state technical, university

Podziękowania:

Praca była finansowana przez Moskiewski Techniczny Uniwersytet Samochodowy i Budowy Dróg

AGNIESZKA WDOWIAK
Kielce University of Technology
e-mail: awdowiak@tu.kielce.pl
JANUSZ BROL
Silesian University of Technology
e-mail: janusz.brol@polsl.pl

Manuscript submitted 2019.10.16 - revised 2019.10.16,
initially accepted for publication 2019.10.17, published in September 2019

METHODS OF STRENGTH GRADING OF STRUCTURAL TIMBER – COMPARATIVE ANALYSIS OF VISUAL AND MACHINE GRADING ON THE EXAMPLE OF SCOTS PINE TIMBER FROM FOUR NATURAL FOREST REGIONS OF POLAND

METODY SORTOWANIA WYTRZYMAŁOŚCIOWEGO TARCICY KONSTRUKCYJNEJ – ANALIZA PORÓWNAWCZA SORTOWANIA WIZUALNEGO I MASZYNOWEGO NA PRZYKŁADZIE POLSKIEJ TARCICY SOSNOWEJ Z CZTERECH KRAIN PRZYRODNICZO-LEŚNYCH

DOI: 10.30540/sae-2019-016

Abstract

The article covers the strength grading system methodology for construction timber. The presented analysis identified important issues concerning the verification of structural and geometric characteristics during construction timber strength grading by visual and machine method. The following considerations specified the guidelines for the classification of coniferous construction timber in sawmills. The paper also presents the results of the visual and machine classification performed for Scots pine timber from four natural forest regions of Poland. As a result of the conducted research it was stated that the use of machine classification equipment allows obtaining a larger amount of pine timber with better mechanical properties and eliminating the rejected timber.

Keywords: construction timber, strength grading, visual method, machine method, wood defects, structural and geometric characteristics

Streszczenie

Artykuł obejmuje metodykę sortowania wytrzymałościowego tarcicy konstrukcyjnej. Przedstawiona analiza określiła ważne zagadnienia dotyczące weryfikacji cech strukturalnych i geometrycznych w trakcie sortowania wytrzymałościowego tarcicy konstrukcyjnej metodą wizualną oraz metodą maszynową. Poniższe rozważania skonkretyzowały wytyczne służące klasyfikacji tarcicy konstrukcyjnej iglastej w tartakach. W pracy ukazano również wyniki badań klasyfikacji wizualnej i maszynowej sosnowej tarcicy konstrukcyjnej pochodzącej z czterech krain przyrodniczo-leśnych Polski. W efekcie przeprowadzonych badań stwierdzono, że wykorzystanie urządzeń do klasyfikacji maszynowej umożliwia uzyskanie większej ilości sztuk tarcicy sosnowej o lepszych właściwościach mechanicznych oraz zniwelowanie liczebności tarcicy odrzuconej.

Słowa kluczowe: tarcica konstrukcyjna, sortowanie wytrzymałościowe, metoda wizualna, metoda maszynowa, wady drewna, cechy strukturalne i geometryczne

1. INTRODUCTION

The demand for construction timber has been steadily increasing in recent years. To ensure structural safety of a building, construction timber must have a guaranteed strength, thus must be strength graded.

1. WPROWADZENIE

W ostatnich czasach sukcesywnie wzrasta zapotrzebowanie na tarcicę konstrukcyjną. Tarcica konstrukcyjna z uwagi na bezpieczeństwo budowli musi odznaczać się gwarantowaną wytrzymałością, zatem

The strength grading according to the method used allows determining flexural modulus of the timber either indirectly (visual method) or directly (machine method). Standards and tests in strength grading of construction timber (initially by visual method only) appeared in countries with highly developed industry: USA, Canada, Finland, Sweden and the United Kingdom.

In 1977, the United Nations Economic Commission for Europe formulated an international standard-setting recommendation – ECE Recommended Standard. It was used in many European countries to develop national standards for construction timber strength grading (e.g. in Poland). Most of the standards introduced 3 grading classes for construction timber graded by visual method (in Poland, Germany, Austria, England, France and Slovakia). The Irish and Spanish standards introduced 2 grading classes, while the Portuguese – 1 class, the Scandinavian – 4 grading classes.

The purpose of visual grading for all standards is to ensure that each piece of timber is inspected by a wood quality controller and classified in a specific class depending on structural wood defects as well as defects in shape and processing. The use of machines, on the other hand, created the need to amend the standards concerning strength grading and to supplement them with the rules of machine-method grading. Currently, the EN 14081-1:2016-03 standard has been introduced [1]. When classifying timber with the machine method, it is assigned to strength classes according to EN 338 [2]. Two other standards are associated with this standard, which define the methods of testing the physical and mechanical wood properties and the determination of their characteristic values (EN 408 [3] and EN 384 [4]).

In different EU countries, grading with visual method produces timber classified into different grading classes (e.g. in Poland – KW, KS, KG; in Germany and Austria – S7, S10, S13; in France – ST-I, ST-II, ST-III; in Scandinavian countries – T3, T2, T1, T0; in Spain – ME1, ME2, and in Slovakia – S0, SI, SII), [5]. The visual method is currently used in Poland for timber strength grading. The qualifications to grade using this method are obtained through special training completed with a practical exam. After passing the examination, each participant is granted personal license to strength-grade timber according to PN-D-94021 [6] and to issue a declaration of conformity of a graded batch of timber according to the requirements of this standard [5, 7-9].

musi być sortowana wytrzymałościowo. Sortowanie wytrzymałościowe zależnie od zastosowanej metody umożliwia w sposób pośredni (metoda wizualna) albo bezpośredni (metoda maszynowa) wyznaczyć moduł sprężystości tarcicy. Normy i opracowania w obszarze wytrzymałościowego sortowania tarcicy konstrukcyjnej (na początku wyłącznie metodą wizualną) pojawiły się w krajach o wysoko rozwiniętym przemyśle: USA, Kanada, Finlandia, Szwecja i Wielka Brytania.

W 1977 roku Europejska Komisja Gospodarcza ONZ sformułowała międzynarodowe zalecenie normalizacyjne – ECE Recommended Standard. Posłużyło ono w wielu krajach europejskich do opracowania krajowych norm dotyczących sortowania wytrzymałościowego tarcicy konstrukcyjnej (m.in. w Polsce). Większa część norm wprowadziła 3 klasy sortownicze dla tarcicy konstrukcyjnej sortowanej wytrzymałościowo metodą wizualną (w Polsce, Niemczech, Austrii, Anglii, Francji i Słowacji). Normy irlandzka oraz hiszpańska wprowadziły 2 klasy sortownicze, a portugalska – 1 klasę, skandynawska – 4 klasy sortownicze. Celem wizualnego sortowania dla wszystkich norm jest dokładne obejrzenie każdej sztuki tarcicy przez brakarza oraz sklasyfikowanie jej do określonej klasy, z uwagi na występujące w sortowanej tarcicy wady strukturalne drewna oraz wady kształtu i obróbki. Wykorzystanie natomiast maszyn wywołało konieczność nowelizacji norm, dotyczących sortowania wytrzymałościowego oraz uzupełnienia ich o zasady sortowania metodą maszynową. Obecnie wprowadzono normę EN 14081-1:2016-03 [1]. Klasyfikując metodą maszynową tarcicę, przyporządkowuje się ją do klas wytrzymałościowych według EN 338 [2]. Z tą normą są związane dwie inne normy, które określają sposoby badań właściwości fizycznych oraz mechanicznych drewna oraz wyznaczenie ich wartości charakterystycznych (EN 408 [3] i EN 384 [4]).

W różnych krajach UE sortując metodą wizualną uzyskuje się tarcicę sklasyfikowaną do różnych klas sortowniczych (np. w Polsce – KW, KS, KG; w Niemczech i Austrii – S7, S10, S13; we Francji – ST-I, ST--II, ST-III; w krajach skandynawskich – T3, T2, T1, T0; w Hiszpanii – ME1, ME2, na Słowacji – S0, SI, SII), [5]. W Polsce obecnie wykorzystuje się do wytrzymałościowego sortowania tarcicy metodę wizualną. Uprawnienia do sortowania tą metodą uzyskuje się poprzez specjalne szkolenie zakończone egzaminem praktycznym. Po zdaniu egzaminu każdy uczestnik otrzymuje imienne uprawnienia do wytrzymałościowego sortowania tarcicy według PN-D-94021 [6] i wystawiania deklaracji zgodności sortowanej partii tarcicy zgodnie z wymaganiami tej normy [5, 7-9].

The results presented in point 4 are based on the research conducted during the preparation of the doctoral dissertation by one of the article authors [10-14].

2. STRENGTH GRADING WITH MACHINE METHOD

Visual strength grading is a slow and time-consuming process. Its productivity in cubic metres per hour is low. In addition, this grading is burdened by human factor errors, i.e. the grading result is determined by who is grading. Grading results can be unequal when two wood quality controllers grade the same batch of timber. The grading person in the moment of ambiguous situations subconsciously lowers the classes of timber [15]. Visual grading is flawed, so ways to grade without flaws by using special machines were initiated. These involve machines that do not destroy or damage the graded timber during the strength grading process. The aim of the machine designers was to develop devices with a simple and objective determination of wood characteristics, highly correlated with its strength properties. Wood properties with the use of machines are more correlated with wood strength properties than the properties determined during visual grading [5, 16].

Mechanical strength grading dates back to the sixties. The use of machines enables the combination of several simultaneously analyzed wood characteristics. The combinations of these characteristics are more correlated with the strength wood properties than each characteristic separately [5]. These machines meet standard requirements, such as full-size construction timber grading and non-destructive grading. Grading machines are based on the measurement of specific wood characteristics, which can be determined in a non-destructive method and are correlated with the wood bending. The greater the correlation between the tested characteristic and its bending strength, the more genuine the grading results of the machine are.

The use of grading machines allows obtaining objective results, and additionally modern machines grade more efficiently than human. Automatic, computer-controlled and efficient machines can be integrated into automatic process lines for the production of e.g. glued laminated timber (BSH – Brettschichtholz) or solid construction timber (KVH – Konstruktionsvollholz). In these lines, the grading machines are combined with circular cross-cut saws

Wyniki przedstawione w punkcie 4 oparte są na badaniach przeprowadzonych podczas przygotowywania rozprawy doktorskiej jednego z autorów artykułu [10-14].

2. SORTOWANIE WYTRZYMAŁOŚCIOWE METODĄ MASZYNOWĄ

Sortowanie wytrzymałościowe metodą wizualną jest procesem powolnym oraz czasochłonnym. Jego wydajność w metrach sześciennych na godzinę jest niska. Dodatkowo to sortowanie jest obarczone „czynnikiem ludzkim", czyli wynik sortowania jest uwarunkowany tym, kto sortuje. Wyniki sortowania mogą być niejednakowe, gdy dwóch brakarzy przesortuje tę samą partię tarcicy. Sortujący człowiek w momencie niejednoznacznych sytuacji (tzw. sztuki graniczne) podświadomie zaniża klasy tarcicy [15]. Sortowanie metodą wizualną jest obciążone wadami, wobec tego zapoczątkowano szukanie takich sposobów sortowania, które nie byłyby obarczone tymi defektami poprzez zastosowanie specjalnych maszyn. Muszą być to maszyny, które podczas sortowania nie niszczyłyby ani nie uszkadzały sortowanej tarcicy. Celem projektantów maszyn było opracowanie urządzeń o prostym oraz obiektywnym określeniu cech drewna, wysoko skorelowanych z jego właściwościami wytrzymałościowymi. Właściwości drewna z zastosowaniem maszyn są bardziej skorelowane z wytrzymałościowymi właściwościami drewna niż właściwości wyznaczone podczas sortowania metodą wizualną [5, 16].

Maszynowe sortowanie wytrzymałościowe sięga lat sześćdziesiątych ubiegłego wieku. Wykorzystanie maszyn umożliwia kombinację równocześnie kilku analizowanych cech drewna. Kombinacje tych cech są bardziej skorelowane z właściwościami wytrzymałościowymi drewna niż każda cecha odrębnie [5]. Maszyny te spełniają kilka podstawowych wymagań, m.in. zapewnienie sortowania pełnowymiarowej tarcicy konstrukcyjnej oraz nieniszczący sposób sortowania. Maszyny wytrzymałościowe do sortowania tarcicy opierają się na pomiarze określonych cech drewna, które można wyznaczyć w sposób nieniszczący i są skorelowane z wytrzymałością drewna na zginanie. Im większa następuje korelacja pomiędzy badaną cechą a jego wytrzymałością na zginanie, tym bardziej są prawdziwe wyniki sortowania maszyny.

Wykorzystanie maszyn do sortowania pozwala na uzyskanie wyników obiektywnych, dodatkowo współczesne maszyny sortują wydajniej niż człowiek. Automatyczne, sterowane komputerowo i wydajne maszyny można wkomponować w automatyczne linie technolowhich, due to the grading results, cut out board fragments with unacceptable wood defects.

Due to the principle of operation of these machines, they can be classified in two groups:

1. Machines operating on the principle of flexural modulus determination, when timber is assigned to a specific strength class. Two types of these devices can be listed here:
   - Bending machines, the test piece is flexibly bent. With a constant bending force and specified support spacing, the deflection is determined, and with a constant deflection value, the bending force is determined. The data and dimensions of the bending element allow determining flexural modulus at bending. This module is correlated with the wood strength. The strength in these machines is determined by the lowest flexural modulus value for the timber. This allows detecting the weakest cross-section in the graded element. Unfortunately, it is not possible to test the ends of boards with this method (about 0.5 m at both ends).
   - Machines operating on the principle of dynamic flexural modulus impose the tested timber density determination. There are solutions in which each graded element is measured and weighed (usually on a cross conveyor) and in which it is enough to enter the average species density into the computer controlling the machine (without weighing each piece of timber). Thanks to a single blow to the front of the graded timber, it vibrates freely. Special measuring instruments analyse the vibrations as a function of time and determine the frequency of these vibrations (the first harmonic component). With the vibration frequency and timber length and density, a dynamic flexural modulus – average for the whole element – is determined. Here, the flexural modulus depends solely on the length and density of the component to be tested, so that timber of any cross-sectional dimension can be tested with these machines. With this method it is not possible to determine the position of the weakest cross-section. These machines include: Grade Master, Dynagrade, Mobile Timber Grader and Viscan. There are also ultrasound machines for timber grading. An ultrasound generating head is placed in one timber face and a receiving head in the other. The time of ultrasound transfer in wood at a known distance (length of graded timber) shall be determined.

giczne do produkcji np. drewna klejonego warstwowo z tarcicy (BSH – Brettschichtholz) albo drewna konstrukcyjnego litego klejonego na długość (KVH – Konstruktionsvollholz). W liniach tych maszyny sortujące są zestawione z pilarkami tarczowymi poprzecznymi, które z uwagi na wyniki sortowania wycinają fragmenty desek z niedopuszczalnymi wadami drewna.

Z uwagi na zasadę działania wymienionych maszyn można je zaliczyć do dwóch grup:

1. Maszyny działające na zasadzie wyznaczania modułu sprężystości, gdy tarcica jest przyporządkowywana do określonej klasy wytrzymałościowej. Tutaj można wyliczyć dwa rodzaje tych urządzeń:
   - Maszyny działające na zasadzie zginania, badany element jest uginany sprężyście. Przy stałej sile zginającej oraz określonym rozstawie podpór wyznaczana jest strzałka ugięcia, natomiast przy stałej strzałce ugięcia określana jest siła zginająca. Dane i wymiary zginanego elementu umożliwiają wyznaczenie modułu sprężystości przy zginaniu. Moduł ten jest skorelowany z wytrzymałością drewna. Określnikiem wytrzymałości w tych maszynach jest najmniejsza wartość modułu sprężystości wyliczona dla badanej sztuki tarcicy. Pozwala to na wykrycie najsłabszego przekroju w sortowanym elemencie. Niestety nie da się tą metodą zbadać końcówek desek (po około 0,5 m z obu końców).
   - Maszyny działające na zasadzie pomiaru dynamicznego modułu sprężystości wymuszają podanie gęstości badanej tarcicy. Są rozwiązania, w których każdy sortowany element jest mierzony oraz ważony (zwykle na przenośniku poprzecznym) i w których wystarczy wprowadzić do komputera sterującego maszyną średnią gęstość gatunkową (bez ważenia każdej sztuki tarcicy). Dzięki pojedynczym uderzeniom w czoło sortowanej sztuki tarcicy wprowadza się ją w drgania swobodne. Specjalne przyrządy pomiarowe analizują drgania w funkcji czasu i wyznaczają częstotliwość tych drgań (pierwszą harmoniczną). Mając częstotliwość drgań własnych oraz długość i gęstość tarcicy, wyznacza się dynamiczny moduł sprężystości – średni dla całego elementu. Tutaj moduł sprężystości zależy wyłącznie od długości oraz gęstości badanego elementu, dlatego maszynami tymi można badać tarcicę o dowolnych wymiarach przekroju poprzecznego. Taką metodą nie da się określić położenia najsłabszego przekroju. Do tych maszyn należą: Grade Master, Dynagrade, Mobile

Having the time, it is possible to calculate the ultrasound speed, then at a known density of wood – dynamic flexural modulus. Triomatic applies here.

2. Machines operating on the principle of screening the graded element without coming into contact with it. Gamma or X-rays are used to screen the element to determine its characteristics (e.g. density, knottiness index) correlated with the wood strength. These include: Finnograder II and IsoGreComat [16]. Recently, the screening machines for graded timber were equipped with modules scanning the surfaces of the examined timber with optical systems using light of different wavelengths and laser light. This group includes GoldenEye 702 (see Fig. 1), [15]. GoldenEye 702 determines: density, dimensions, texture, recognizes knots, cracks, wanes, curvature, warpage of timber. In case of colour television cameras, this machine also detects decay, sapstain, pitch pockets, bark pockets and decayed knots. It is used in production plants [5]: construction timber glued laminated from sawn timber (BSH), solid construction timber glued lengthwise for finger-joint timber (KVH), structural elements for the U.S. market (2”x4” system).

a)

b)

Timber Grader oraz Viscan. Stosuje się również urządzenia sortujące tarcicę przy wykorzystaniu ultradźwięków. Do jednego czoła tarcicy umieszczana jest głowica generująca ultradźwięki, a do drugiego głowica odbiorcza. Wyznacza się czas przejścia ultradźwięków w drewnie na znanym odcinku (długości sortowanej tarcicy). Mając czas, można wyliczyć prędkość ultradźwięków, potem przy znanej gęstości drewna – dynamiczny moduł sprężystości. Można tutaj zaliczyć Triomatic.

2. Maszyny działające na zasadzie podświetlania sortowanego elementu, nie stykając się z nim. Prześwietlając badany element promieniami gamma albo X, określa się cechy (np. gęstość, sękatość) skorelowane z wytrzymałością drewna. Tutaj można zaliczyć: Finnograder II oraz IsoGreComat [16]. Ostatnio maszyny prześwietlające sortowaną tarcicę zaopatrzone zostały w moduły skanujące powierzchnie badanej tarcicy przy zastosowaniu systemów optycznych wykorzystujących światło o różnych długościach fal i światło laserowe. Do tej grupy można zaliczyć GoldenEye 702 (rys. 1), [15]. GoldenEye 702 wyznacza gęstość, wymiary, układ włókien, rozpoznaje sęki, pęknięcia, obliny, krzywizny, zwichrowania tarcicy. W przypadku kamer telewizji kolorowej ta maszyna wykrywa także zgniliznę, siniznę, pęcherze żywiczne, zakorki, sęki zepsute. Jest ona wykorzystywana w zakładach produkcyjnych [5]: drewno konstrukcyjne klejone warstwowo z tarcicy (BSH), drewno konstrukcyjne lite klejone na długość na miniwczepy (KVH), elementy konstrukcyjne na rynek amerykański (system 2”x4”).

Fig. 1. GoldenEye 702 [15]: a – timber screening with X-rays, b – general view of the device

Rys. 1. GoldenEye 702 [15]: a – prześwietlanie tarcicy promieniami X, b – widok ogólny urządzenia

The highest correlation coefficient with the wood strength is determined by: flexural modulus at bending and combinations of the following characteristics: flexural modulus + knottiness index, flexural modulus + density, density + knottiness index. Modern grading machines operate on the measurement of at least one of the above combinations, preferably correlated with the wood strength. The progress of science and technology changes only the applied methods and measuring devices.

Taking into account the possibility of integration into the production line, the first strength grading machines can be divided into two groups:

1. Machines which may constitute an integral part of an automated production line (should have a sufficiently high capacity, automatic timber feeding and graded timber collection (on-line operating machines).
2. Machines that make up a separate link in the production process (low productivity, manual timber feeding for grading and collection of graded timber), off-line operating machines.

In the nineties, further machines were developed which, due to their principle of operation, cannot be included in either of the two groups. These were the following EuroGreComat and Grade Master solutions. EuroGreComat had two independent principles of operation: the element was simultaneously X-rayed and bent during grading. Bending of the board made it possible to determine the flexural modulus, and X-ray – the timber density and knottiness index (see Fig. 2). The designers of this machine opted for a combination of wood properties, correlation coefficients with bending, tensile and compressive strength of wood are equal to or higher than 0.8.

Najwyższy współczynnik korelacji z wytrzymałością drewna wyznacza moduł sprężystości przy zginaniu i kombinacje następujących cech: moduł sprężystości + sękatość, moduł sprężystości + gęstość, gęstość + sękatość. Współczesne maszyny do sortowania działają na pomiarze przynajmniej jednej z wymienionych wyżej kombinacji, najlepiej skorelowanej z wytrzymałością drewna. Postęp nauki oraz techniki zmienia wyłącznie zastosowane metody oraz urządzenia pomiarowe.

Biorąc pod uwagę możliwość włączenia do linii produkcyjnej pierwsze maszyny do sortowania wytrzymałościowego można podzielić na dwie grupy:

1. Maszyny, które mogą stanowić integralną część zautomatyzowanego ciągu produkcyjnego (powinny mieć dostatecznie wysoką wydajność, automatyczne podawanie tarcicy do sortowania oraz odbioru tarcicy przesortowanej), maszyny pracujące on-line.
2. Maszyny, które tworzą oddzielne ogniwo procesu produkcyjnego (niskiej wydajności, ręczne podawanie tarcicy do sortowania oraz odbiór tarcicy przesortowanej), maszyny off-line.

W latach 90. ubiegłego wieku powstały kolejne maszyny, których z uwagi na wykorzystaną zasadę działania nie da się włączyć do żadnej z wymienionych wcześniej dwóch grup. Stanowiły one następujące rozwiązania EuroGreComat oraz Grade Master. EuroGreComat posiadał dwie niezależne zasady działania: element podczas sortowania był jednocześnie prześwietlany promieniami X i uginany. Uginanie deski umożliwiało wyznaczenie modułu sprężystości, a prześwietlanie – gęstość oraz sękatość badanej tarcicy (rys. 2). Projektanci tej maszyny zdecydowali się na kombinację właściwości drewna, współczynniki korelacji z wytrzymałościami na zginanie, rozciąganie oraz ściskanie drewna są równe albo wyższe niż 0,8.

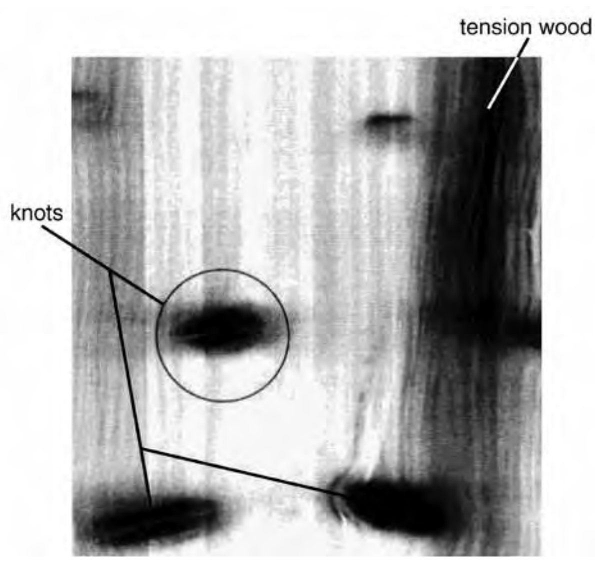


Fig. 2. The X-ray image of the graded element using EuroGreComat [15]

Rys. 2. Postać rentgenowskiego obrazu sortowanego elementu z wykorzystaniem EuroGreComatu [15]

Grade Master (see Fig. 3) is a device operating on the principle of dynamic flexural modulus measurement. This was done by blowing the front of a board on a cross conveyor with a suitable hammer. This impact caused the board to vibrate. The frequency of these vibrations is taken into account. The frequency of these vibrations and the density of the whole piece made it possible to determine the dynamic flexural modulus. Each board for density determination was weighed and measured. Additionally, this device was equipped with a set of four cameras, scanning the surface of the board from four sides. The camera system determined the knottiness index of the analyzed element, other defects and wood properties affecting the strength: cracks, pitch pocket, bark pockets, larval galleries and wane.

Grade Master (rys. 3) to urządzenie działające na zasadzie pomiaru dynamicznego modułu sprężystości. Zachodziło to poprzez uderzenie w czoło deski znajdującej się na przenośniku poprzecznym, odpowiednim młotkiem. To uderzenie wzbudzało w desce drgania. Do pomiaru jest brana częstotliwość tych drgań. Częstotliwość tych drgań i gęstość całej sztuki umożliwiała wyznaczenie dynamicznego modułu sprężystości. Każda deska do wyznaczenia gęstości była zważona oraz zmierzona. Dodatkowo to urządzenie było zaopatrzone w zestaw czterech kamer, skanując powierzchnię deski z czterech stron. System kamer określał sękatość analizowanego elementu i inne wady oraz właściwości drewna wpływające na wytrzymałość: pęknięcia, pęcherze żywiczne, zakorki, chodniki owadzie, oblinę.

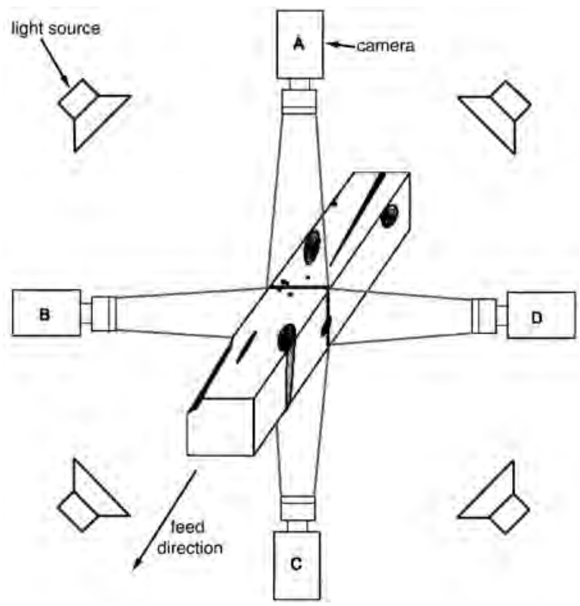


Fig. 3. The principle of operation of the scanner in the Grade Master grading device [15]: A, B, C, D cameras

Rys. 3. Zasada działania skanera w urządzeniu do sortowania Grade Master [15]: A, B, C, D kamery

3. VISUAL STRENGTH GRADING

Due to the building safety, construction timber should have guaranteed strength, i.e. it should be strength graded by the wood quality controllers in sawmills. Strength grading, depending on the visual method applied (indirect method) or machine method (direct method), allows determining the flexural modulus of timber [14]. Knowing the flexural modulus and density of construction timber, it is possible to predict its strength [5, 13]. The strength classification with visual method allows achieving higher homogeneity of timber in relation to mechanical properties than in general purpose materials [14].

The construction timber classification with visual method is specified in the PN-D-94021:2013-10

3. SORTOWANIE WYTRZYMAŁOŚCIOWE METODĄ WIZUALNĄ

Z uwagi na bezpieczeństwo budynków tarcica konstrukcyjna powinna odznaczać się gwarantowaną wytrzymałością, czyli powinna być przesortowana wytrzymałościowo przez brakarzy w tartakach. Sortowanie wytrzymałościowe zależnie od wykorzystanej metody wizualnej (sposób pośredni) lub maszynowej (sposób bezpośredni) pozwala określić moduł sprężystości tarcicy [14]. Znając moduł sprężystości i gęstość tarcicy konstrukcyjnej, można przewidzieć jej wytrzymałość [5, 13]. Stosowanie klasyfikacji wytrzymałościowej metodą wizualną umożliwia uzyskanie większej, niż w materiałach ogólnego przeznaczenia, jednorodności tarcicy w odniesieniu do właściwości mechanicznych [14].

standard. The scope of this standard covers edged coniferous timber, rough or planed timber, dry or green timber, thickness from 22 mm and minimum cross-section 2000 mm^2. Conditionally, the standard may be applied to the classification of construction coniferous timber with a thickness of less than 22 mm but not less than 19 mm, taking into account the minimum cross-section condition [14].

The PN-D-94021:2013-10 [6] standard applies to timber of the following wood: Scots pine (*Pinus sylvestris* L.), the Norway spruce (*Picea abies* (L.) Karst), the European silver fir (*Abies alba* Mill.), the European larch (*Larix decidua* Mill), and Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco). It includes not only the principles of timber classification in visual strength grading, but also specifies the moisture, dimensional, quality and marking requirements as well as test procedures for determining these characteristics [15, 17].

The PN-D-94021:2013-10 standard [6, 14] distinguishes:

a) strength-graded construction coniferous timber, strength-sorted – timber graded due to strength characteristics or parameters and defects in shape and processing;
b) marginal zone – one of two zones located along the entire length of each timber side with a width equal to ¼ of the plane width;
c) the worst cross-section – the conventional cross-section in the area of the maximum accumulation of knots, in particular in the marginal zones of timber, covering the projection plane of knots;
d) knottiness index – the share of knots in the worst cross-section of timber;
e) marginal area knotting index – the index covering one of the two marginal zones, i.e. one where knots occupy a larger area, the so-called worse margin;
f) general knotting index – knotting index referring to the entire timber cross-section (Fig. 4).

To define the construction timber quality class graded with visual method, the type, dimensions and degree of defect intensity that determine the timber strength characteristics, as well as the wood growth ring index and density are taken into account. Coniferous construction timber is grouped into three quality classes and the following markings are used: KW – choice class, KS – middle quality class and KG – lower quality class. Quality classes of particular species of coniferous construction timber have been qualified to strength classes included in PN-EN 1995-

Klasyfikacja tarcicy konstrukcyjnej metodą wizualną określona jest w normie PN-D-94021:2013-10 [6]. Zakresem tej normy objęta jest tarcica iglasta obrzynana, szorstka lub strugana, sucha albo mokra, grubości od 22 mm i minimalnym przekroju poprzecznym 2000 mm^2. Warunkowo normę można zastosować do klasyfikacji tarcicy konstrukcyjnej iglastej o grubości poniżej 22 mm, ale nie mniejszej niż 19 mm, uwzględniając warunek minimalnego przekroju poprzecznego [14].

Norma PN-D-94021:2013-10 [6] dotyczy tarcicy z sosny zwyczajnej (*Pinus sylvestris* L.), świerka pospolitego (*Picea abies* (L.) Karst), jodły pospolitej (*Abies alba* Mill.), modrzewia europejskiego (*Larix decidua* Mill), daglezji zielonej (jedlicy zielonej) (*Pseudotsuga menziesii* (Mirb.) Franco). Obejmuje ona nie tylko zasady klasyfikacji tarcicy przy sortowaniu wytrzymałościowym metodą wizualną, ale także podaje wymagania wilgotnościowe, wymiarowe, jakościowe, oznakowania i procedury badawcze wyznaczenia tych cech [15, 17].

Norma PN-D-94021:2013-10 [6, 14] wyodrębnia:

a) tarcicę konstrukcyjną iglastą sortowaną wytrzymałościowo – tarcica sortowana z uwagi na cechy lub parametry wytrzymałościowe oraz wady kształtu i obróbki;
b) strefę marginalną – jedną z dwóch stref, znajdującą się na całej długości każdego z boków tarcicy, o szerokości równej ¼ szerokości płaszczyzny;
c) przekrój poprzeczny najgorszy – przekrój umowny, występujący w obszarze maksymalnego nagromadzenia sęków, w szczególności w strefach marginalnych, obejmujący płaszczyznę rzutowania sęków;
d) wskaźnik sękatości – udział sęków na powierzchni najgorszego przekroju poprzecznego tarcicy;
e) wskaźnik sękatości strefy marginalnej (USM) – wskaźnik obejmujący jedną z dwóch stref marginalnych, czyli taką, gdzie sęki zajmują większą powierzchnię, tzw. gorszy margines;
f) ogólny wskaźnik sękatości (USC) – wskaźnik sękatości odnoszący się do całego przekroju poprzecznego tarcicy (rys. 4).

Do zdefiniowania klasy jakości tarcicy konstrukcyjnej sortowanej metodą wizualną uwzględnia się rodzaj, wymiary i stopień nasilenia wad, które decydują o cechach wytrzymałościowych tarcicy, jak również słoistość i gęstość drewna. Iglastą tarcicę konstrukcyjną grupuje się na trzy klasy jakości oraz stosuje się poniższe oznaczenia: KW – klasa wyborowa, KS – klasa średniej jakości, KG – klasa gorszej jakości. Klasy jakości poszczególnych gatunków tarcicy konstrukcyjnej iglastej zostały zakwalifikowane do klas wytrzymałościowych, zawartych w PN-EN 1995-1-1:2010

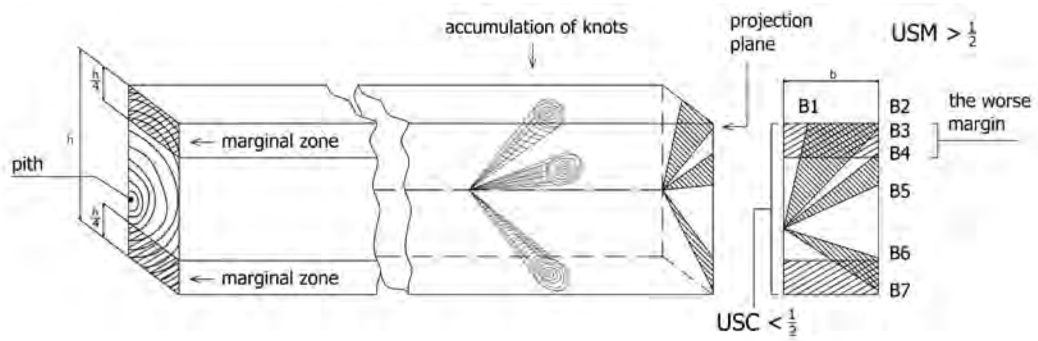
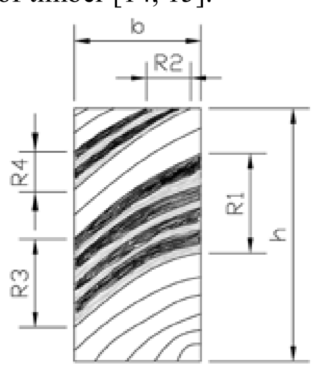


Fig. 4. Ways of projecting knots (USM – marginal area knotting index; USC – general knotting index; B1, B2, B3, B4, B5, B6, B7 – points determining the diameter of knots on the side and on the plane) [14, 15]

Rys. 4. Sposoby rzutowania sęków (USM – wskaźnik sękatości strefy marginalnej; USC – ogólny wskaźnik sękatości; B1, B2, B3, B4, B5, B6, B7 – punkty wyznaczające średnicę sęków na boku i na płaszczyźnie) [14, 15]

1-1:2010 [18], National Annex PN-EN 1995-1-1:2010 [19]. Construction timber quality graded with visual method is determined by visual inspection in the area with the highest intensity of defects according to PN-D-94021:2013-10 [6]. Dimensions of permissible defects are determined in accordance with PN-EN 1310:2000 [20] and PN-EN 1311:2000 [21] standards. During the grading process, the weakest cross-section with the largest accumulation of defects, e.g. knots, should be found in the timber. The strength of the weakest cross-section determines the strength of the entire timber. When testing the weakest cross-section, the entire timber length is determined, granting a class or rejecting it. During visual grading it is also necessary to determine the defects and structural features of wood, such as: knots, cracks, growth ring index, slope of grain, presence of decay and insect damage, defects in processing and shape: wanes, distortion [5, 11-15, 22-23]. In case a reaction wood (compression wood) is present, a cross-section is found in which there is an enlargement of the summer wood zone in the annual rings (see Fig. 5). The width of the reaction wood zone determined in one plane and on one side refers to the circumference of the cross-section of timber [14, 15].

[18], Załącznik krajowy PN-EN 1995-1-1:2010 [19]. Tarcicę konstrukcyjną sortowaną metodą wizualną pod względem jakościowym określa się dokonując oględzin w obszarze największego nasilenia wad według PN-D-94021:2013-10 [6]. Wymiary dopuszczalnych wad wyznacza się zgodnie z PN-EN 1310:2000 [20] i PN-EN 1311:2000 [21]. Podczas sortowania należy w ocenianej sztuce tarcicy odnaleźć najsłabszy przekrój, w którym znajduje się największe skupienie wad, np. sęków. Wytrzymałość najsłabszego przekroju rozstrzyga o wytrzymałości całej sztuki tarcicy. Badając najsłabszy przekrój, określa się tarcicę na całej długości, przydzielając jej odpowiednią klasę lub uznając ją jako odrzut. Podczas sortowania wizualnego należy również określić wady i cechy strukturalne drewna, jak: sęki, pęknięcia, słoistość, skręt włókien, obecność zgnilizny i chodników owadzich, wady obróbki i kształtu: obliny, krzywizny [5, 11-15, 22-23]. W przypadku obecności drewna reakcyjnego (twardzicy), wyszukuje się przekrój poprzeczny, w którym występuje poszerzenie strefy drewna późnego w słojach rocznych (rys. 5). Szerokość strefy drewna reakcyjnego wyznaczonej na jednej płaszczyźnie i na jednym boku odnosi się do obwodu przekroju poprzecznego tarcicy [14, 15].



$$R = \frac{R1+R2+R3+R4}{2(b+h)}$$

Fig. 5. Measurement of the reactive wood share according to PN-D-94021:2013-10 [6, 14, 15]

Rys. 5. Pomiar udziału drewna reakcyjnego wg PN-D-94021:2013-10 [6, 14, 15]

Permissible defects of construction timber graded with visual method depending on its quality class are summarised in Table 1.

Dopuszczalne wady tarcicy konstrukcyjnej sortowanej metodą wizualną w zależności od jej klasy jakości zestawiono w tabeli 1.

Table 1. Permissible defects of construction timber graded with visual method according to PN-D-94021:2013-10 [6, 14-15]
Tabela 1. Dopuszczalne wady tarcicy konstrukcyjnej sortowanej metodą wizualną według PN-D-94021:2013-10 [6, 14-15]

THE CLASSIFICATION BASIS		KW	KS		KG	
			Variant 1	Variant 2	Variant 1	Variant 2
KNOTS, REGARDLESS OF QUALITY, EXPRESSED AS A KNOTTING INDEX USM*		≤ 1/4	≤ 1/2	≤ 1/2	> 1/2	
OVER THE ENTIRE CROSS-SECTION OF TIMBER USC		4≤ 1/4 4≤ 1/4 4≤ 1/3	≤ 1/4	≤ 1/2	≤ 1/3	
SLOPE OF GRAIN (diagonal grain path)		≤ 7% (1:14)	≤ 10% (1:10)		≤ 16% (1:6)	
CRACKS, RESIN POCKETS, BARK POCKETS AND CATFACES:	deep, not crossing to the face, sides and opposite plane (not including defects less than 300 mm in length)	permissible, length up to ¼ of the piece length and not longer than 600 mm	permissible, length up to $^1/_4$ of the piece length and not longer than 600 mm		permissible, length up to $^1/_4$ of the piece length and not longer than 900 mm	
		depth up to $^1/_3$ of the piece thickness	depth up to $^1/_2$ of the piece thickness		depth up to $^2/_3$ of the piece thickness	
	frontal non-crossing, crossing and circular	permissible, length up to 1/1 piece width	permissible, length up to 1/1 piece width		permissible, length up to 1 $^1/_2$ piece width	
DECAY		impermissible	impermissible		impermissible	
INSECT DAMAGE		impermissible	impermissible		impermissible	
SAPSTAIN		permissible	permissible		permissible	
REACTION WOOD (COMPRESSION WOOD)		permissible up to $^1/_5$ of the girth	permissible up to $^1/_5$ of the girth		permissible up to $^1/_5$ of the girth	
GROWTH RING INDEX		≤ 4 mm	≤ 6 mm		≤ 10 mm	
Minimum DENSITY of timber** at a moisture content of 20%		≥ 450 kg/m^3	≥ 420 kg/m^3		≥ 400 kg/m^3	
WANE is permitted along the entire length of two edges of one plane or one side, occupying a total of		up to ¼ thickness and ¼ width of timber piece	up to $^1/_4$ thickness and $^1/_4$ width of timber piece		- at a distance of up to 300 mm from faces u[to $^1/_3$ of the thickness and $^1/_3$ of the piece width - at a distance of more than 300 mm from faces up to $^1/_3$ of the thickness and $^1/_3$ of the piece width	
BOW - LONGITUDINAL CURVATURE OF PLANES		≤ 10 mm	≤ 10 mm		≤ 20 mm	
SPRING - LONGITUDINAL CURVATURE OF THE SIDES		≤ 8 mm	≤ 8 mm		≤ 12 mm	
TWIST IN RELATION UP TO WIDTH		≤ 1 mm/25 mm	≤ 1 mm/25 mm		≤ 2 mm/25 mm	
CUP - CROSS CURVATURE TO WIDTH		≤ 1 mm/25 mm	≤ 1 mm/25 mm		≤ 2 mm/25 mm	
CRACKS, KERF WAVINESS		permissible within the thickness and width deviations specified for basic dimensions				
PARALLELISM OF PLANES AND SIDES		planes should be parallel to each other, sides of edged timber should be perpendicular to planes; deviations from parallelism should be within the limits of acceptable thickness and width deviations specified for the basic dimensions				
NON-PERPENDICULARITY OF FACES		faces should be perpendicular to planes and sides; deviations from perpendicularity should be within the permissible deviations in timber length				

* For die squares and balks, the margins specified for each of the four longitudinal timber surface areas are taken into account.
** When the growth ring index criterion is met, the density is not taken into account.

4. THE RESULTS OF THE CONSTRUCTION TIMBER CLASSIFICATION TESTS

Structural Scots pine sawn timber with from 10% to 15% moisture content from these four natural forest regions of Poland was used in the tests:

– Mazowiecko-Podlaska Natural Forest Region, raw material from the Garwolin Forest Inspectorate;
– Małopolska Natural Forest Region, raw material from the Przedbórz Forest Inspectorate;
– Śląska Natural Forest Region, raw material from the Kędzierzyn-Koźle Forest Inspectorate, and
– Carpathian Natural Forest Region, raw material from the Piwniczna Forest Inspectorate.

4.1. Visual classification

Visual strength grading was performed in accordance with PN-D-94021:2013-10 [6].

During the classification, the pine timber thickness, width and length were measured. During the visual inspection of each timber piece, all structural and geometric features of the timber, such as the thickness, width and length of the timber, were measured: knots, slope of grain, cracks, resin pockets, bark pockets and bark scorches, decay, insect damage, sapstain, compression wood, growth ring index (rate f growth), density, wane, bow, spring, twist, cup, scratches, kerf waviness, unevenness of planes and sides and non-parallelism of faces. Knots, usually their size and position on the cross-section of the graded timber, were the decisive factor determining the timber quality class. The weakest cross-section, with the largest knot or the largest accumulation of knots, was found along the entire timber piece length. After determining the weakest cross-section, the ratio of knot (knots) area to the area of the entire cross-section, including the knot area in the marginal zone to the area of this zone, was determined. The "worse" margin was selected during the classification, i.e. the one on the cross-section where knots occupy a larger area. Auxiliary sheets of paper with the dimensions of the cross-section of the graded piece, on which the knots [5, 13] were projected, were used to determine the growth ring index coefficients.

As a result of the grading timber from Mazowiecko – Podlaska Natural Forest Region, the largest number of timber pieces was obtained in the KW class (6 pieces) and in the KS class (13 pieces) in relation to the results of timber grading from other regions. The reject accounted for 41.7% of the total timber from this region. For the timber obtained from the Małopolska Natural Forest Region, 4

4. WYNIKI BADAŃ KLASYFIKACJI TARCICY KONSTRUKCYJNEJ

Do badań zastosowano sosnową tarcicę konstrukcyjną o wilgotności od 10% do 15%, pochodzącą z czterech krain przyrodniczo-leśnych Polski:

– Mazowiecko-Podlaska Kraina Przyrodniczo-Leśna, surowiec z Nadleśnictwa Garwolin,
– Małopolska Kraina Przyrodniczo-Leśna, surowiec z Nadleśnictwa Przedbórz,
– Śląska Kraina Przyrodniczo-Leśna, surowiec z Nadleśnictwa Kędzierzyn-Koźle,
– Karpacka Kraina Przyrodniczo-Leśna, surowiec z Nadleśnictwa Piwniczna.

4.1. Klasyfikacja wizualna

Wytrzymałościowe sortowanie metodą wizualną wykonano zgodnie z normą PN-D-94021:2013-10 [6].

Podczas klasyfikacji dokonano pomiaru grubości, szerokości i długości tarcicy sosnowej. W trakcie oględzin każdej sztuki tarcicy wykonano pomiar wszystkich występujących w danej sztuce tarcicy cech strukturalnych i geometrycznych, takich jak: sęki, skręt włókien, pęknięcia, pęcherze żywiczne, zakorki i zabitki, zgnilizna, chodniki owadzie, sinizna, twardzica, słoistość, gęstość, oblina, krzywizny podłużne płaszczyzn i boków, wichrowatość w odniesieniu do szerokości, krzywizny poprzeczne w odniesieniu do szerokości, rysy, falistość rzazu, nierównoległość płaszczyzn i boków, nieprostopadłość czół. Zwykle decydującym wskaźnikiem o klasie jakości tarcicy stanowiły sęki, zazwyczaj ich wielkość oraz położenie na przekroju poprzecznym sortowanej sztuki tarcicy. Na całej długości sztuki tarcicy wyszukano najsłabszy przekrój, w którym znajduje się największy sęk lub największe skupisko sęków. Po określeniu najsłabszego przekroju określono stosunek powierzchni sęka (sęków) do powierzchni całego przekroju poprzecznego, także powierzchnię sęka w strefie marginalnej do powierzchni tej strefy. W czasie klasyfikacji selekcjonowano margines „gorszy", czyli ten na przekroju poprzecznym, którego sęki zajmują większą powierzchnię. Do ustalenia współczynników sękatości zastosowano pomocnicze kartki papieru o wymiarach przekroju poprzecznego sortowanej sztuki, na której rzutowano znajdujące się w niej sęki [5, 13].

W wyniku sortowania tarcicy z Mazowiecko-Podlaskiej Krainy Przyrodniczo-Leśnej uzyskano najwięcej sztuk tarcicy w klasie KW (6 sztuk) oraz w klasie KS (13 sztuk) w odniesieniu do wyników sortowania tarcicy pochodzącej z pozostałych krain. Odrzut stanowił 41,7% całości tarcicy z tej krainy. Dla tarcicy pozypieces were graded in the KW class and 10 pieces in the KS class. The most numerous group was rejected timber – 29 pieces, which was higher by 7 pieces than the KG class. Śląska Natural Forest Region was distinguished by 3 timber pieces in the KW class and 8 pieces in the KS class. 28 rejected timber pieces were obtained in this region were obtained, which constituted 43.1% in relation to the whole timber batch from this region. 26 timber pieces were assigned to the KG class. Timber obtained from the Carpathian Natural Forest Region was clearly the worst of the entire tested batch. Only 1 timber piece in the KW class and 3 timber pieces in the KS class were graded. The highest number of rejected pieces was graded, as many as 29 pieces, which accounted for 58% of the total number of timber from this region. Mainly by knots (15 pieces) determined the rejection. In the remaining cases, wanes (5 pieces), cracks (2 pieces), slope of grain (1 piece), and other defects (2 pieces) [12, 13].

On the basis of the tests, the obtained results of visual classification were compared with the percentage of particular quality classes of coniferous timber, taking into account its origin (Table 2).

skanej z Małopolskiej Krainy Przyrodniczo-Leśnej wysortowano w klasie sortowniczej KW – 4 sztuki, a w klasie KS – 10 sztuk. Najliczniejszą grupę stanowiła tarcica przyporządkowana jako odrzut – 29 sztuk, która była większa o 7 sztuk od klasy KG. Śląska Kraina Przyrodniczo-Leśna odznaczała się 3 sztukami tarcicy w klasie KW i 8 sztukami w klasie KS. Uzyskano w tej krainie 28 sztuk tarcicy należącej do odrzutu, co stanowiło 43,1% w stosunku do całej partii tarcicy z tej krainy. Do klasy KG przyporządkowano 26 sztuk tarcicy. Tarcia pozyskana z Karpackiej Krainy Przyrodniczo-Leśnej była wyraźnie najgorsza z całej badanej partii. Wysortowano tylko 1 sztukę tarcicy w klasie KW i 3 sztuki tarcicy w klasie KS. Wysortowano największą liczbę sztuk, aż 29 jako odrzut, co stanowiło 58% całości tarcicy z tej krainy. O odrzuceniu tych sztuk przede wszystkim zadecydowały sęki (15 sztuk). W pozostałych przypadkach obliny (5 sztuk), pęknięcia (2 sztuki), skręt włókien (1 sztuka) i inne wady (2 sztuki) [12, 13].

Na podstawie badań zestawiono uzyskane wyniki klasyfikacji wizualnej z udziałem procentowym poszczególnych klas jakości iglastej tarcicy z uwzględnieniem jej pochodzenia (tabela 2).

Table 2. Results of classes obtained as a result of visual strength grading tests according to PN-D-94021:2013-10 [5, 6, 12, 13]

Tabela 2. Wyniki uzyskanych klas w efekcie badań sortowania wytrzymałościowego metodą wizualną według PN-D-94021:2013-10 [5, 6, 12, 13]

REGION	KW	KS	KG	rejected
Mazowiecko-Podlaska Natural Forest Region	10%	21.67%	26.67%	41.67%
Małopolska Natural Forest Region	6.15%	15.38%	33.85%	44.60%
Śląska Natural Forest Region	4.62%	12.31%	40.00%	43.08%
Karpacka Natural Forest Region	2.00%	6.00%	34.00%	58.00%
TOTAL	5.83%	14.17%	33.75%	46.25%

The table shows that 46.25% of the tested pine timber was rejected, 33.75% of the timber was classified as the KG class, 14.17% of the timber was graded in the KS class, while only 5.83% of the timber was qualified to the best KW class. According to PN-EN 1995-1-1:2010 [18] and the National Annex to PN-EN 1995-1-1:2010 [19], the KS quality class corresponds to strength class C24, whereas the KG class to C20.

4.2. Machine classification

The test was performed under industrial conditions using WoodEye Cross Cut. 10 pieces of pine timber (37×48 mm cross section) were selected from

Z tabeli wynika, że 46,25% badanej tarcicy sosnowej stanowił odrzut, 33,75% tarcicy określono jako klasę KG, 14,17% tarcicy wysortowano w klasie KS, natomiast tylko 5,83% tarcicy zakwalifikowano do najlepszej klasy KW. Zgodnie z PN-EN 1995-1-1:2010 [18] i Załącznikiem krajowym PN-EN 1995-1-1:2010 [19] klasa jakości KS odpowiada klasie wytrzymałościowej C24, natomiast klasa KG – C20.

4.2. Klasyfikacja maszynowa

Badanie zostało wykonane w warunkach przemysłowych przy użyciu urządzenia WoodEye Cross Cut. Z każdej krainy przyrodniczo-leśnej Polski wybrano each natural forest region of Poland. The length of the tested elements was 4.05 m. Each timber piece reached the WoodEye machine, then, after classification, it was transferred via a feed conveyor to a box appropriate for a given class. WoodEye is an automatic visual wood control system. It determines the quality of boards and the inspection is carried out visually to identify defects: knots, cracks, size or position flaws.

The results of the visual and WoodEye Cross Cut strength grading of timber batches are shown in Table 3.

po 10 sztuk tarcicy sosnowej o wymiarze przekroju poprzecznego 37×48 mm. Długość badanych elementów wynosiła 4,05 m. Każda sztuka tarcicy docierała do urządzenia WoodEye, następnie po klasyfikacji przenośnikiem podawczym trafiała do boksu odpowiedniego dla danej klasy.

WoodEye jest automatycznym wizualnie systemem kontrolującym drewno. Określa jakość desek, a kontrolę przeprowadza się wizualnie, żeby określić defekty: sęki, pęknięcia, błędy wielkości czy pozycji.

Wyniki badań sortowania wytrzymałościowego partii tarcicy metodą wizualną i przy użyciu urządzenia WoodEye Cross Cut przedstawiono w tabeli 3.

Table 3. Comparison of grading classes during visual classification and with WoodEye Cross Cut of timber originating from different natural forest regions of Poland

Tabela 3. Porównanie klas sortowniczych podczas klasyfikacji wizualnej i przy użyciu urządzenia WoodEye Cross Cut, pochodzącej z poszczególnych krain przyrodniczo-leśnych Polski

No	Visual grading KW, pcs.	WoodEye grading, pcs.	Visual grading KS, pcs.	WoodEye grading, pcs.	Visual grading KG, pcs.	WoodEye grading, pcs.	Visual grading rejection, pcs.	WoodEye grading rejection, pcs.
A	1	2	2	4	3	4	4	0
B	1	2	1	3	3	4	5	1
C	1	2	1	2	2	4	6	2
D	0	1	1	2	1	3	8	4

Grading timber with WoodEye Cross Cut results in a significant increase in the number of pieces in the higher classes in relation to the visual grading results and a decrease in the number of pieces in the lowest grades. Visual grading resulted in only 3 pieces of the KW-class timber (8%) and 7 pieces (18%) with WoodEye Cross Cut. Rejected timber in visual grading constituted 58%, while with WoodEye Cross Cut – 18%.

Sortując tarcicę przy użyciu urządzenia WoodEye Cross Cut, uzyskuje się znaczny wzrost liczby sztuk przyporządkowanych do wyższych klas w odniesieniu do wyników sortowania metodą wizualną, a spadek ilości sztuk tarcicy najniższej klasy. W wyniku sortowania wizualnego uzyskano tylko 3 sztuki tarcicy klasy KW (8%), a przy zastosowaniu urządzenia WoodEye Cross Cut – aż 7 sztuk (18%). Tarcica przeznaczona na odrzut przy sortowaniu wizualnym stanowiła 58%, zaś przy sortowaniu z wykorzystaniem urządzenia WoodEye Cross Cut – 18%.

5. SUMMARY

The changes taking place on the market of building materials caused a growing demand for construction timber with guaranteed strength. The presented analysis presented the most important issues related to the verification of structural and geometric characteristics during strength grading of construction timber by visual and machine method. In conclusion, the basic guidelines, which can be used for the classification of construction timber in sawmills, were specified [14]. On the

5. PODSUMOWANIE

Zmiany zachodzące na rynku materiałów budowlanych spowodowały rosnące zapotrzebowanie na tarcicę konstrukcyjną o wytrzymałości gwarantowanej. Ukazana analiza przedłożyła najistotniejsze zagadnienia związane z weryfikacją cech strukturalnych i geometrycznych w trakcie sortowania wytrzymałościowego tarcicy konstrukcyjnej metodą wizualną i maszynową. W wyniku przeanalizowanych rozważań sprecyzowano bazowe wytyczne, które mogą posłużyć przy klasyfikacji tarcicy konstrukcyjnej iglastej basis of the conducted test it was found that during visual structural pine timber classification there is a significant amount of rejections, as much as 46.25% in the whole batch. It is worth noting that similar results of strength grading of Scots pine structural timber form Poland were obtained in publications [5, 24] and Scots pine structural timber form German obtained in publication [25]. Grading with WoodEye Cross Cut allows for a significant increase in the number of pieces of timber in higher classes with better mechanical properties and a decrease in the number of the lowest classes, which is a sufficient financial benefit for the owners of sawmills applying this classification [10].

w tartakach [14]. Na podstawie przeprowadzonych badań stwierdzono, że podczas klasyfikacji wizualnej sosnowej tarcicy konstrukcyjnej występuje znaczna ilość odrzutów, aż 46,25% w całej partii. Warto zauważyć, że zbliżone wyniki sortowania wytrzymałościowego sosnowej tarcicy konstrukcyjnej z Polski uzyskano w publikacjach [5, 24], a sosnowej tarcicy konstrukcyjnej z Niemiec w publikacji [25]. Sortowanie na podstawie urządzenia WoodEye Cross Cut umożliwia uzyskanie znacznego przyrostu liczebności sztuk tarcicy w wyższych klasach o lepszych właściwościach mechanicznych oraz spadek liczebności klas najniższych, co stanowi dostateczną korzyść finansową dla właścicieli tartaków stosujących omówioną klasyfikację [10].

REFERENCES

[1] PN-EN 14081-1:2016-03 Konstrukcje drewniane – Drewno konstrukcyjne sortowane wytrzymałościowo o przekroju prostokątnym – Część 1: Wymagania ogólne (Timber structures – Strength-graded construction timber with rectangular cross section – Part 1: General requirements).

[2] PN-EN 338:2016-06 Drewno konstrukcyjne – Klasy wytrzymałości (Construction timber – Strength classes).

[3] PN-EN 408+A1:2012 Konstrukcje drewniane – Drewno konstrukcyjne lite i klejone warstwowo – Oznaczanie niektórych właściwości fizycznych i mechanicznych (Wooden structures – Structural solid and glulam wood – Designation of certain physical and mechanical properties).

[4] PN-EN 384:2016-10 Drewno konstrukcyjne – Oznaczanie wartości charakterystycznych właściwości mechanicznych i gęstości (Construction timber – Determination of characteristic mechanical properties and density).

[5] Krzosek S.: *Wytrzymałościowe sortowanie polskiej sosnowej tarcicy konstrukcyjnej różnymi metodami* (*Strength-sorting of the Polish pine structural sawn wood using various methods*), Wydawnictwo SGGW, Warszawa 2009.

[6] PN-D-94021:2013-10 Tarcica konstrukcyjna iglasta sortowana metodami wytrzymałościowymi (Construction timber graded by strength methods).

[7] Dzbeński W., Kozakiewicz P., Krzosek S.: *Wytrzymałościowe sortowanie tarcicy konstrukcyjnej*, Wydawnictwo SGGW, Warszawa 2005.

[8] Dzbeński W., Krzosek S., Kozakiewicz P.: *Właściwości, metody sortownicze i normalizacja tarcicy budowlano-konstrukcyjnej w programie przedsięwzięć szkoleniowych i wdrożeniowych*, „Przemysł Drzewny" 2000, 12, pp. 13–16.

[9] Szukała R., Szumiński G.: *Drewno konstrukcyjne dla budownictwa w świetle aktualnych przepisów,* „Rynek Drzewny" 2003, 3, pp. 30–31.

[10] Wdowiak A.: *Właściwości strukturalno-wytrzymałościowe zginanych belek drewnianych wzmocnionych kompozytami włóknistymi* (*Structural and strength properties of bent wooden beams reinforced with fibrous composites*), doctoral dissertation, Kielce University of Technology, Kielce 2018.

[11] Wdowiak A.: *Defects in structural timber*, "Structure and Environment" 2017, Vol. 9, No. 2, pp. 112–122.

[12] Rudziński L., Wdowiak A.: *Strength and structural properties of structural timber*, "Structure and Environment" 2016, Vol. 8, No. 2, pp. 103–108.

[13] Wdowiak A.: *Using the visual method to sort Polish pine structural sawn timber with respect to strength. Technical Transactions*, „Czasopismo Techniczne. Budownictwo" 2016, Issue 2-B, pp. 219–224.

[14] Wdowiak A.: *Badanie cech strukturalnych i geometrycznych podczas sortowania wytrzymałościowego tarcicy konstrukcyjnej metodą wizualną* (*Studying the structural and geometrical features during strength-sorting of structural sawn wood using the visual method*), „Przegląd Budowlany" 2017, Vol. 88, No. 12, pp. 42–46.

[15] Kozakiewicz P., Krzosek S.: *Inżynieria materiałów drzewnych*, Wydawnictwo SGGW, Warszawa 2013.

[16] Gloss P.: *Die maschinelle Sortierung von Schnittholz*, Stand der Technik – Vergleich der Verfahren, Holz-Zentralblatt, 13, 1982.

[17] Kozakiewicz P.: *Fizyka drewna w teorii i zadaniach. Wybrane zagadnienia*, Wydawnictwo SGGW, Warszawa 2003.

[18] PN-EN 1995-1-1:2010 Eurokod 5 Projektowanie konstrukcji drewnianych – Część 1-1: Postanowienia ogólne – Reguły ogólne i reguły dotyczące budynków (Design of wooden structures – Part 1-1: General – provisiobs – General and building rules).

[19] PN-EN 1995-1-1:2010/NA:2010 Eurokod 5 Projektowanie konstrukcji drewnianych – Część 1-1: Postanowienia ogólne – Reguły ogólne i reguły dotyczące budynków (Design of wooden structures – Part 1-1: General – provisions – General and building rules).

[20] PN-EN 1310:2000 Drewno okrągłe i tarcica – Metody pomiaru cech (Round wood and timber – Methods of measuring characteristics).
[21] PN-EN 1311:2000 Drewno okrągłe i tarcica – Metody pomiaru biologicznej degradacji (Methods for measuring biological degradation).
[22] Krzysik F.: *Nauka o drewnie* (*Wood Science*), Państwowe Wydawnictwo Naukowe, Warszawa 1975.
[23] Wdowiak A., Kroner A.: *Wpływ niejednorodności struktury zginanych belek z drewna klejonego na efekt ich wzmocnienia*, „Materiały Budowlane" 2017, 1, pp. 87–89.
[24] Adell Almazan F.J., Hermoso Prieto E., Arriaga Martiteguti F., Richter C.: *Comparison of the Spanish Visual strength trading standard for structural sawn timber (UNE 56544) with the German one (DIN 4074) for Scots pine (Pinus sylvestris L.) from Germany*, Holz Roh Werks, 2008 6, pp. 253–258.
[25] Krzosek S., Grześkiewicz M.: *Strength grading Polish-grown Pinus Silvestris L. structural timber using Timber Grader MTG and visual method*, "Annals of Warsaw University of Life Sciences – SGGW. Forestry and Wood Technology " 2008, No. 66, pp. 26–31.

Acknowledgments:
The work was financed by Kielce University of Technology.

Podziękowania:
Praca była finansowana przez Politechnikę Świętokrzyską, Wydział Budownictwa i Architektury.


environment
environment

ANATOLIY PAVLENKO
ANNA MARIA SLOWAK
Kielce University of Technology
e-mail: apavlenko@tu.kielce.pl

Manuscript submitted 2018.09.03 – revised 2018.10.15,
initially accepted for publication 2019.05.24, published in September 2019

PHYSICO-CHEMICAL CHARACTERISTICS OF FUEL GAS MIXTURES

CHARAKTERYSTYKA FIZYKOCHEMICZNA MIESZANEK GAZÓW PALIWOWYCH

DOI: 10.30540/sae-2019-017

Abstract

The article presents data on changes in physical and chemical properties of mixtures of generator gases with natural gas and the issue of the optimal ratio of these gases in the mixture. The results of research on the basic properties of flammable mixture of generator gases and natural gas are presented, on the basis of which the optimal composition of the mixture was proposed.

Keywords: properties of combustible gas mixtures, pyrolysis gas, artificial gas, combustion of gas, mixture, generator gas

Streszczenie

W artykule przedstawiono dane dotyczące zmian właściwości fizycznych i chemicznych mieszanin gazów generatorowych z gazem ziemnym oraz zagadnienie optymalnego stosunku tych gazów w mieszaninie. Przedstawiono wyniki badań podstawowych właściwości palnych mieszaniny gazów generatorowych i gazu ziemnego, na podstawie których zaproponowano optymalny skład mieszaniny.

Słowa kluczowe: właściwości palnych mieszanek gazów, gaz pirolityczny, gaz sztuczny, spalanie mieszaniny gazów, gaz generatorowy

1. INTRODUCTION

Insufficient deposits of natural gas and other fossil fuels, as well as a significant share of natural gas in the thermal energy production process, lead to the need to address the problem of natural gas diversification and the wider use of renewable energy sources, including biomass energy. Generator gas can be the solution to this problem.

Direct combustion of solid biomass in many cases gives a positive economic effect, however, it is associated with expensive boiler house reconstruction, the need to provide space for fuel storage and environmental problems of fuel combustion. Generating and burning generator gas is a good alternative. There is also the problem of burning synthetic gases in a mixture with natural gas using the same gas burners.

1. WPROWADZENIE

Niewystarczające pokłady gazu ziemnego i innych paliw kopalnych, a także znaczny udział gazu ziemnego w procesie wytwarzania energii cieplnej prowadzą do konieczności rozwiązania problemu dywersyfikacji gazu ziemnego i szerszego wykorzystania odnawialnych źródeł energii, w tym energii biomasy. Gaz generatorowy może być rozwiązaniem tego problemu.

Bezpośrednie spalanie biomasy stałej w wielu przypadkach daje pozytywny efekt ekonomiczny, wiąże się to jednak z kosztowną przebudową kotłowni, potrzebą zapewnienia miejsca na składowanie paliwa oraz problemami środowiskowymi spalania paliw. Generowanie i spalanie gazu generatorowego jest dobrą alternatywą. Pojawia się również problem spalania gazów syntetycznych w mieszaninie z gazem ziemnym przy użyciu tych samych palników gazowych.

2. PURPOSE OF RESEARCH

Investigation of the characteristics of the generator gas, natural gas and determination of their optimal share in the fuel mixture.

3. SUBJECT OF RESEARCH

The characteristics of the combustion process and the design of gas burners depend on the composition of the gas or combustible mixture and their physical and chemical properties. The main feature of generator gases is the change in their composition and characteristics during production. This results in a continuous change of important combustion efficiency features, such as:

– normal flame spread speed;
– volume of combustion products and secondary air demand for total gas combustion;
– stability, penetration and flame separation;
– temperature of combustion products, brightness of the flame and heat of combustion, composition of gases;
– enthalpy of combustion products, thermal power of the burner and heat recovery from the gas combustion device;
– characteristics of the fuel mixture.

Table 1 shows the average characteristics of natural gas and generator gas.

2. CEL BADAŃ

Badanie charakterystyki gazu generatorowego, gazu ziemnego i określenie optymalnego ich udziału w mieszance paliwowej.

3. PRZEDMIOT BADAŃ

Charakterystyka procesu spalania i konstrukcja palników gazowych zależą od składu gazu lub mieszaniny palnej i ich właściwości fizykochemicznych. Główną cechą gazów generatorowych jest zmiana ich składu i charakterystyki w czasie produkcji. Powoduje to ciągłą zmianę ważnych cech wydajnościowych spalania, takich jak:

– normalna prędkość rozprzestrzeniania się płomienia;
– objętość produktów spalania i zapotrzebowanie na powietrze wtórne do całkowitego spalenia gazu;
– stabilność, zjawisko przebicia i separacja płomienia;
– temperatura produktów spalania, jasność płomienia i ciepło spalania, skład gazów;
– entalpia produktów spalania, moc cieplna palnika i odzysk ciepła z urządzenia do spalania gazu;
– charakterystyka mieszanki paliwowej.

Tabela 1 pokazuje uśrednione charakterystyki gazu ziemnego i generatorowego.

Table 1. Comparative table of basic physical and chemical properties of natural and generator gases

Tabela 1. Tabela porównawcza podstawowych właściwości fizycznych i chemicznych gazu ziemnego i generatorowego

No.	Indicator	Unit of measurement	Natural gas	Pyrolysis gas
1	Lower heat of combustion Q_h^p	kJ/m^3	35895	5426
2	Theoretical air flow V_t	m^3/m^3	9.5	1
3	Volume of combustion products V_{pz} at $\alpha = 1$	m^3/m^3	10.5	1.9
4	Maximum speed flame spread u_h^{max}	m/s	0.37	1.03
5	Maximum velocity of flame propagation with ballast $u_{h\ bal}^{max}$	m/s	0.3677	1.297
6	Burning limits: lower L_h	% vol.	5.005	19.11
	upper L_b	% vol.	15.05	72.4
7	Excess air ratio in within the limits of ignition: on the lower limit α_h	frequencies	1.994	4.163
	on the upper limit α_b	frequencies	0.593	0.375
8	Content of combustible gas mixed with air provided stoichiometric combustion reaction L_{ct}	% vol.	9.5	45.07
9	Gas burning temperature t_{upper}	°C	2763.7	1674.6

We observe a wide range, higher speed of flame spread and lower heat of combustion of the generator gas compared to natural gas despite the higher content of H_2 in the generator gas (up to 25% volume) and CO (up to 26% volume). The lower combustion temperature is conditioned by gas pollution – CO_2 (up to 15% vol.) and N_2 (up to 50% by volume).

The average natural gas composition differs from the genarator gas with higher combustion heat (up to 23 MJ/m^3), a significant amount of CH_4 as well as impurities (Table 2).

Obserwujemy szeroki zakres, większą prędkość rozprzestrzeniania się płomienia oraz mniejsze ciepło spalania gazu generatorowego w porównaniu z gazem ziemnym pomimo większej zawartości H_2 w gazie generatorowym (do 25% objętości) i CO (do 26% objętości). Niższa temperatura spalania uwarunkowana jest zanieczyszczeniami gazu – CO_2 (do 15% obj.) i N_2 (do 50% obj.). Średni skład gazu ziemnego różni się od gazu generatorowego wyższym ciepłem spalania (do 23 MJ/m^3), znaczną ilość CH_4, a także zanieczyszczeniami (tabela 2).

Table 2. The average composition of biogas [1]
Tabela 2. Średni skład gazu generatorowego [1]

Component name	CO_2	O_2	CH_4	H_2	N_2	H_2S
Content of components, % vol.	31.7	0.4	67.2	0.1	0.5	0.1

Table 3 shows the characteristics of natural gas, the composition of which varies by months of the year.

Tabela 3 pokazuje charakterystykę gazu ziemnego, którego skład zmienia się w zależności od miesiąca w roku.

Table 3. Some characteristics of natural gas
Tabela 3. Niektóre właściwości gazu ziemnego

Characteristics of gas	January	February	March	June	August
Heat of combustion Q_h^p, kcal/m^3	10138	9250	10656	10660	8390
Theoretical need of the air V_0, m^3/m^3	11.1	10.1	11.6	11.5	8.9
Maximum content CO_2^{max} in products of combustion % obj.	13.1	12.9	13.2	13.3	12.7
Fuel gas density ρ, kg/m^3	0.88	0.78	0.92	0.91	0.68
The upper limit of the flare L^b	18.7	19.8	17.9	18.5	22.4
Excess air ratio at the upper limit ignition α_1^{max}	0.392	0.403	0.395	0.381	0.389
The content of hydrogen in the gas H_2, %	42.4	44.8	37.5	42.2	54.5
Combustion temperature t, °C	2093	2123	2185	2274	1755

The heat of natural gas burning is much higher than the genarator gas due to the content of heavy hydrocarbons. The main feature of artificial gases is the high content of ballast (CO_2 and N_2) in their composition, which worsens the properties of combustible fuel.

Most gas combustion devices that are found in the literature and catalogs of burners [1, 4] have been designed and manufactured to operate on natural gas. The assessment of their ability to work on other types of gaseous fuels or the assessment of gas interchangeability is carried out according to various criteria, but none of them is completely reliable and can not fully assess the possibility of ensuring stability for all types of gaseous fuel. The characteristics of the burner's operation change significantly when

Ciepło spalania gazu ziemnego jest znacznie większe niż gazu pirolitycznego ze względu na zawartość ciężkich węglowodorów. Stężenie wodoru w gazie ziemnym jest praktycznie takie samo jak w pirolitycznym. Główną cechą gazów sztucznych jest wysoka zawartość balastu (CO_2 i N_2) w ich składzie, który pogarsza właściwości paliwa palnego.

Większość urządzeń do spalania gazu, które znajdują się w literaturze i katalogach palników [1, 4], zostały zaprojektowane i wyprodukowane do pracy na gazie ziemnym. Ocena ich zdolności do pracy przy innych rodzajach paliw gazowych lub ocena zamienności gazów jest przeprowadzana według różnych kryteriów, ale żadne z nich nie jest całkowicie niezawodne i nie może w pełni ocenić możliwości zapewnienia stabilności przy wszystkich rodzajach paliwa switching from one gas to another. These are such features as:

– ensuring constant thermal power of the burner and thermal power of the installation during the transition from one gas to another, N = const;
– stable burner's operation, no breakdown phenomena and flame separation in the entire range of the burner adjustment;
– the constancy of the composition of toxic compounds of combustion products (CO, NO_x, nitrogen oxides, soot, etc.);
– immutability of flame propagation speed.

Essentially, flammable gases can be called interchangeable, if one gas can be replaced with another without additional adjustment of the burner.

The reason for the existence of different criteria of interchangeability is that they are not obtained on the basis of basic rights, but are empirical. Gases as well as burner constructions have various limitations.

Thus, the Wobbe criterion essentially assesses the possibility of ensuring constant thermal power of the unit in the transition from one combustible gas to another:

– simple Wobbe criterion:

$$Wo_1 = Wo_2 = \cdots Wo_n = const \pm 5\% \qquad (1)$$

$$\frac{Q^p_{H1}}{\sqrt{\rho_1}} = \frac{Q^p_{H2}}{\sqrt{\rho_2}} = \cdots = \frac{Q^p_{Hn}}{\sqrt{\rho_n}} = const \pm 5\% \qquad (2)$$

where: Wo_1, Wo_2, Wo_n are simple Wobbe criteria, which are determined for flammable gases based on the combustion heat (Q_p) and the relative density (ρ_i) under normal or standard conditions; the extended Wobbe criterion estimates the possibility of using the same gas combustion device, provided that different gas pressure (P_i) is maintained in front of the burner:

$$Q^p_{H1}\sqrt{\frac{P_1}{\rho_1}} = Q^p_{H2}\sqrt{\frac{P_2}{\rho_2}} = \cdots = Q^p_{Hn}\sqrt{\frac{P_n}{\rho_n}} = const \pm 5\% \qquad (3)$$

In Great Britain, the equivalent hydrocarbons method is used to determine exchangeability. Weaver's criterion takes into account the differences in the normal velocity of the flame spread, as well as the stability of flame separation and explosion of various gases. The assessment of boundaries and completeness of gas combustion is carried out using the French exchange rate method. One of these

gazowego. Charakterystyka pracy palnika znacznie zmienia się w przypadku przejścia z jednego gazu na drugi. Są to takie cechy jak:

– zapewnienie stałości mocy cieplnej palnika i mocy cieplnej instalacji podczas przejścia z jednego gazu do drugiego, N = const;
– stabilność pracy, brak zjawiska przebicia i separacja płomienia w całym zakresie regulacji palnika;
– niezmienność składu toksycznych związków produktów spalania (CO, NO_x, tlenków azotu, sadzy itp.);
– niezmienność prędkości rozprzestrzeniania się płomienia.

Zasadniczo gazy palne mogą być nazwane wymiennymi, jeżeli jeden gaz może być zastąpiony innym bez dodatkowej regulacji palnika.

Powodem istnienia różnych kryteriów zamienności jest to, że nie są one uzyskiwane na podstawie podstawowych praw, ale są empiryczne. Gazy, a także konstrukcje palników mają różne ograniczenia. Zatem kryterium Wobbego zasadniczo ocenia możliwość zapewnienia stałej mocy cieplnej jednostki w przejściu z jednego palnego gazu do drugiego:

– proste kryterium Wobbego:

$$Wo_1 = Wo_2 = \cdots Wo_n = const \pm 5\% \qquad (1)$$

$$\frac{Q^p_{H1}}{\sqrt{\rho_1}} = \frac{Q^p_{H2}}{\sqrt{\rho_2}} = \cdots = \frac{Q^p_{Hn}}{\sqrt{\rho_n}} = const \pm 5\% \qquad (2)$$

gdzie: Wo_1, Wo_2, Wo_n są wartościami, które określa się dla gazów palnych na podstawie ciepła spalania (Q_p) i gęstości względnej (ρ_i) w warunkach normalnych lub standardowych; rozszerzone kryterium Wobbego szacuje możliwość zastosowania tego samego urządzenia do spalania gazu, pod warunkiem, że przed palnikiem utrzymuje się różne ciśnienie gazu (P_i):

$$Q^p_{H1}\sqrt{\frac{P_1}{\rho_1}} = Q^p_{H2}\sqrt{\frac{P_2}{\rho_2}} = \cdots = Q^p_{Hn}\sqrt{\frac{P_n}{\rho_n}} = const \pm 5\% \qquad (3)$$

W Wielkiej Brytanii do określenia wymienności służy metoda równoważnych węglowodorów. Kryterium Weavera uwzględnia różnice w normalnej prędkości rozprzestrzeniania się płomienia, a także stabilność separacji i wybuchu płomienia różnych gazów. Ocenę granic i kompletność spalania gazów przeprowadza się za pomocą francuskiej metody wskaźników zamienności. Jednym z tych wskaźniindicators is the hydrogen index in the mixture. It should not be greater than 10% of the volume [4].

4. RESULTS

The wide composition spectrum of generator gas leads to the expansion of the range between the lower and upper combustion limits and complicates the stable combustion process without penetration and separation in the burner. The gas mixture becomes flammable in a wide range of concentrations.

Thus, clean generator gas has an ignition limit of αn = 4.15 and αv = 0.375, Δα = 3.775 (Figure 1). With such a wide range of inflammatory values, it is almost impossible to ensure stable combustion without flame explosion in kinetic burners. Increasing the share of natural gas in the mixture can significantly reduce the range of the flames and allow combustion of the gas mixture in the burners. For pure natural gas, the flammability limits are: αn = 2, αv = 0.59, Δα = 1.41 (Figure 1).

Figures 2 and 3 show graphs of changes in the content of a combustible mixture within the limits of ignition and changes in the normal flame spread coefficient depending on the proportion of natural gas in the mixture.

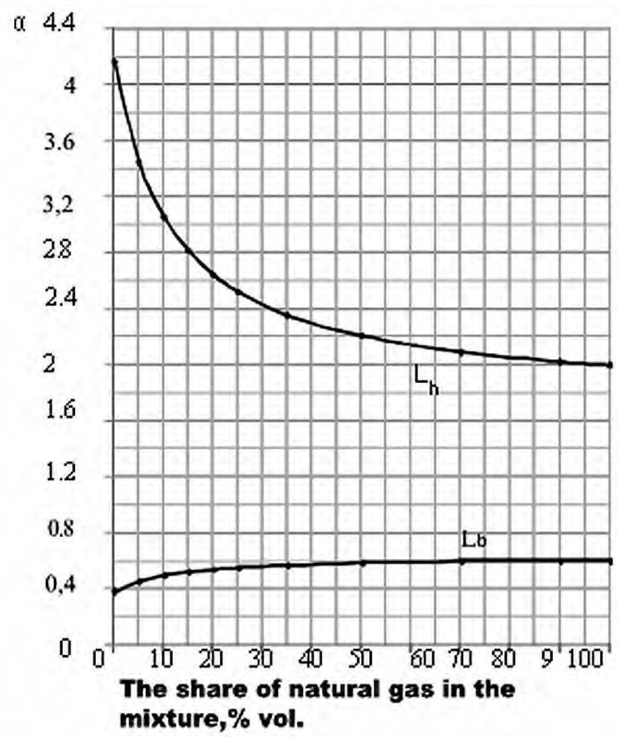


Fig. 1. Coefficients of excess air at the lower and upper limits of ignition

4. WYNIKI BADAŃ

ków jest wskaźnik wodoru w mieszaninie, nie powinien on być większy niż 10% objętości [4].

Szerokie spektrum składu gazów generatorowych prowadzi do rozszerzenia zakresu pomiędzy dolną i górną granicą spalania i komplikuje stabilny proces spalania bez przebicia i separacji w palniku. Mieszanina gazu staje się łatwopalna w szerokim zakresie stężeń.

Zatem czysty gaz generatorowy ma granice zapłonu od αn = 4,15 i αv = 0,375, Δα = 3,775 (rys. 1). Przy tak szerokiej gamie wartości zapalnych prawie niemożliwe jest zapewnienie stabilnego spalania bez wybuchu płomienia w palnikach kinetycznych. Zwiększenie udziału gazu ziemnego w mieszaninie może znacznie zmniejszyć zasięg płomieni i umożliwić spalanie mieszaniny gazów w palnikach. Dla czystego gazu ziemnego granice palności są następujące: αn = 2, αv = 0,59, Δα = 1,41 (rys. 1).

Na rysunkach 2 i 3 przedstawiono wykresy dotyczące zmiany zawartości w mieszaninie palnej w granicach zapłonu i zmiany normalnego współczynnika rozprzestrzeniania się płomienia w zależności od proporcji gazu ziemnego w mieszaninie.

Rys. 1. Współczynniki nadmiaru powietrza przy dolnej i górnej granicy zapłonu

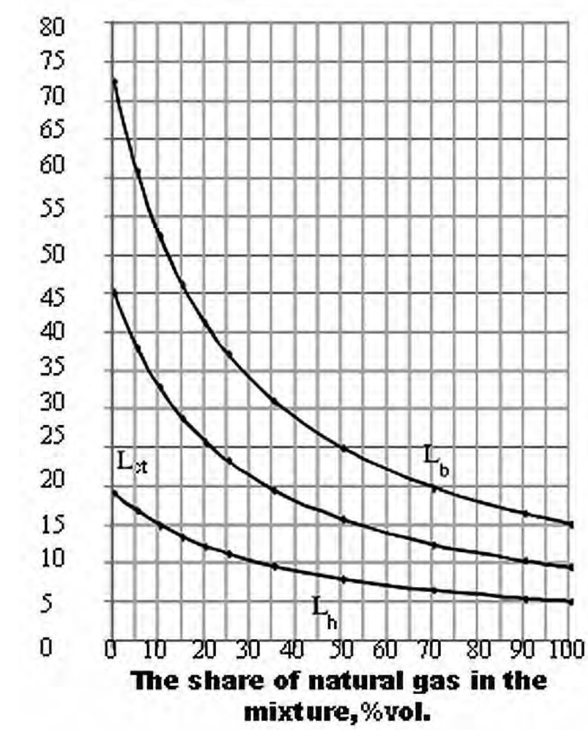


Fig. 2. Gas content at lower and upper limit of ignition and stoichiometric combustion, % vol

Rys. 2. Zawartość gazu przy dolnej i górnej granicy zapłonu i spalaniu stechiometrycznym, % objętości

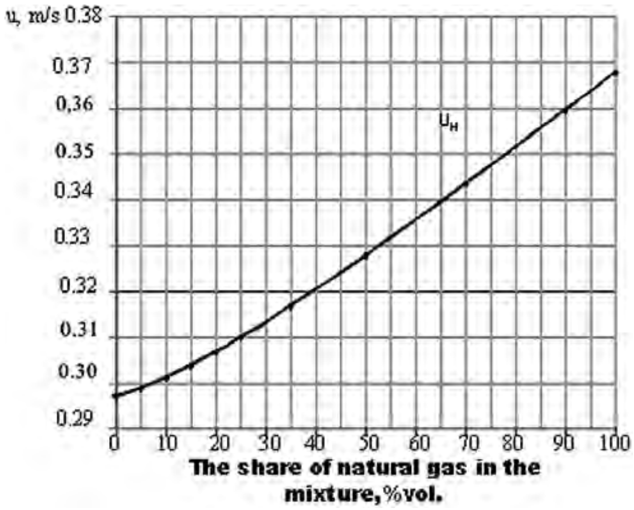


Fig. 3. Normal flame propagation speed, m/s
Rys. 3. Normalna prędkość propagacji płomienia, m/s

The change of gas density is a significant influence on the burners. It changes the loss of gas passing through the nozzle of the burner, which reduces the gas flow rate through the fire holes of the burners, therefore it changes the aerodynamic conditions of the gas mixture with the air blown in and affects the completeness of combustion and the heat output of the burner.

Thus, when the density of the gas changed from 0.5 kg/nm^3 to 1.2 kg/nm^3, the gas consumption decreased from 48 m^3/h to 30 m^3/h (the gas pressure in front of the nozzle was 200 kPa). The influence of gas density and heat of combustion is inversely proportional to the heat output of the burner.

To a certain extent, the dependance on density and gas combustion heat can be used to compensate for optimal combustion conditions, which makes it possible to balance gases. With significant differences in gas density, the amount of heat released in the combustion process is greater. Changes in the composition of natural gas in the density range from 0.6 kg/nm^3 to 0.78 kg/nm^3 have practically no effect on the amount of thermal power of the burner but with the increase of gas density from 0.8 kg/nm^3 to 1.2 kg/nm^3 due to the lower proportion of hydrogen in the gas, the amount of heat increases at 19%.

Studies have shown that for the discussed criteria, generator gases are not interchangeable with natural gas. Combustion of gases with variable amount of hydrogen leads to unstable combustion, therefore the value of thermal energy obtained is unstable. The criterion for differences in the heat transfer process may be the ratio of the amount of carbon to hydrogen in the Cp/Hp combustible gas composition, which affects the flame temperature (Figure 4).

Na działanie palników istotny wpływ ma zmiana gęstości gazu. Powoduje ona zmianę strat gazu przechodzącego przez dyszę palnika, co zmniejsza szybkość przepływu gazu przez otwory ogniowe palników, dlatego zmienia warunki aerodynamiczne mieszaniny gazu z wdmuchiwanym powietrzem i wpływa na kompletność spalania i moc cieplna palnika. Zatem gdy gęstość gazu zmieniła się z 0,5 kg/nm^3 do 1,2 kg/nm^3 zużycie gazu zmniejszyło się z 48 m^3/h do 30 m^3/h (ciśnienie gazu przed dyszą wynosiło 200 kPa). Wartość gęstości i ciepła spalania gazu jest odwrotnie proporcjonalne do wartości mocy cieplnej palnika.

W pewnym zakresie zależność od gęstości i ciepła spalania gazu można wykorzystać do kompensacji uzyskania optymalnych warunków spalania co stwarza możliwość dla zrównoważenia gazów. Przy znacznych różnicach w gęstościach gazów, ilość ciepła wydzielonego w procesie spalania jest większa. Zmiany w składzie gazu ziemnego w zakresie gęstości od 0,6 kg/nm^3 do 0,78 kg/nm^3 praktycznie nie mają wpływu na ilość mocy cieplnej palnika ale wraz ze wzrostem gęstości gazu od 0.8 kg/nm^3 do 1.2 kg/nm^3 z powodu mniejszego udziału wodoru w gazie, ilość ciepła zwiększa się o 19%.

Badania wykazały, że dla omówionych kryteriów gazy generatorowe nie są wymienne z gazem ziemnym. Spalanie gazów z zmienną ilością wodoru prowadzi do niestabilnego spalania dlatego wartość uzyskiwanej energii cieplnej jest niestabilna. Kryterium różnic w procesie wymiany ciepła może być stosunek ilości węgla do wodoru w składzie gazu palnego Cp/Hp, który wpływa na temperaturę płomienia (rys. 4).

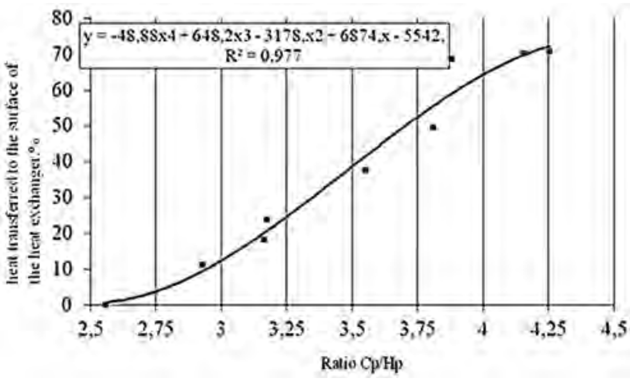


Fig. 4. Effect of gas composition on heat emission in the combustion space.

Rys. 4. Wpływ składu gazu na emisję ciepła w przestrzeni spalania

Decreasing the Cp/Hp ratio leads to a reduction in the amount of heat received by the heating surfaces and to an increase in the temperature of the exhaust gas. It results from the effect of soot, which arises in the intermediate stages of burning in the flame, on the transmission of radiation heat.

Figure 5 shows the effect of hydrogen content in the composition of the artificial gas on the ratio Cp/Hp.

Zmniejszenie stosunku Cp/Hp prowadzi do zmniejszenia ilości ciepła odbieranego przez powierzchnie grzewcze i do zwiększenia temperatury gazów spalinowych. Wynika to z wpływu sadzy, która powstaje w pośrednich stadiach spalania w płomieniu, na przenikanie ciepła promieniowania.

Rysunek 5 pokazuje wpływ zawartości wodoru w składzie gazu sztucznego na stosunek Cp/Hp.

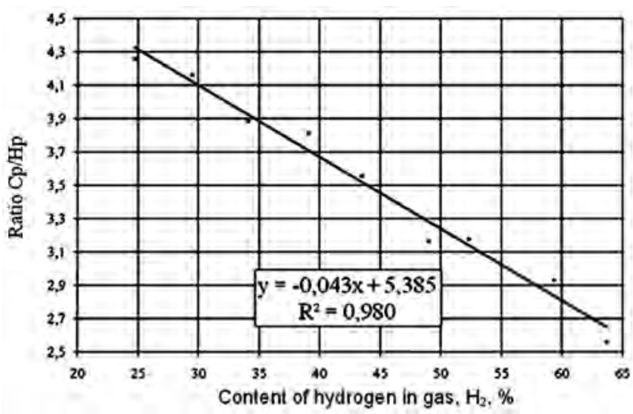


Fig. 5. The effect of the amount of hydrogen in the flammable gas on the ratio Cp/Hp in the elemental gas composition

Rys. 5. Wpływ ilości wodoru w gazie palnym na stosunek Cp/Hp w elementarnej kompozycji gazowej

5. CONCLUSIONS

The tests have shown that getting the interchangeability conditioned by the criterion (Vobbe) is possible only when the natural gas with the generator one is pre-mixed. The share of the generator gas in such a mixture should not exceed 6-11% of the volume. Generator gas can not replace natural gas as a natural alternative. However, it is a source of renewable energy.

The use of generator gases and other synthetic gases whose criteria for interchangeability with natural gas are not within acceptable limits is not possible. Therefore, it is not possible to quickly switch from one type of gaseous fuel to another and to realize the benefits resulting from the use of gaseous fuel compared to the benefits of using solid fuels.

5. PODSUMOWANIE

Badania wykazały, że uzyskanie zamienności warunkowane kryterium (Vobbego) jest możliwe tylko wtedy, gdy wstępnie zostanie zmieszany gaz ziemny z generatorowym. Udział gazu generatorowego w takiej mieszaninie nie powinien przekraczać 6-11% objętości. Gaz generatorowy nie może zastąpić gazu ziemnego, stanowiąc naturalną alternatywę. Jest jednak źródłem energii odnawialnej.

Zastosowanie gazów generatorowych i innych gazów syntetycznych, których kryteria zamienności z gazem ziemnym nie są w dopuszczalnych granicach, nie jest możliwe. W związku z tym nie ma możliwości szybkiego przejścia z jednego rodzaju paliwa gazowego na inne i realizacji korzyści wynikających z zastosowania paliwa gazowego w porównaniu do korzyści wykorzystania paliw stałych.

REFERENCES

[1] Tao Wang Zhenmin, Luoa Hu Wena, Fangming Chen Jun, Deng Jingyu Zhaoa, Zhengchao Guob Jingjing, Lina Kai Kang, Weifeng Wang: *Effects of flammable gases on the explosion of CH4 in air*, "Journal of Loss Prevention in the Process Industries", Vol. 49, Part B, September 2017, pp. 183–190.
[2] Forced Draft Burner handbook. Rielló S.p.A. Legnago – Italy, 2001, p. 171.
[3] Zhen H.S., Leung C.W., Cheung C.S., Huang Z.H.: *Combustion characteristic and heating performance of stoichiometric biogas-hydrogen-air flame*, "International Journal of Heat and Mass Transfer", Vol. 92, January 2016, pp. 807–814.
[4] Natural gas – Quality designation: EN ISO 13686. – Introduced 2007-09-01. – W.: Austrian Standards Institute, 2007, p. 48.

Acknowledgments:
The work was financed by Kielce University of Technology, part of the statutory work No. 05.0.08.00/2.01.01.01.0000 MNSP.IKFB.18.001

Podziękowania:
Praca była finansowana przez Politechnikę Świętokrzyską, w ramach pracy statutowej nr 05.0.08.00/2.01.01.01.0000 MNSP.IKFB.18.001

IRYNA L. KRAVCHENKO

EXTERNAL AND INTERNAL FACTORS OF INFLUENCE ON DEVELOPMENT OF ARCHITECTURE OF NON-FORMAL EDUCATION ESTABLISHMENTS

ZEWNĘTRZNE I WEWNĘTRZNE CZYNNIKI WPŁYWAJĄCE NA ROZWÓJ ARCHITEKTURY PRZEDSIĘBIORSTW EDUKACYJNYCH

Structure and Environment No. 3/2019, vol. 11, p. 177 DOI: 10.30540/sae-2019-013

Abstract

The article sets out the main provisions on internal and external factors of influence on the development of architecture of non-formal education institutions. External factors are represented by a group of socio-economic factors, a technical (technological) factor, a number of political factors and an environmental factor. Internal factors that influence the development of the architecture of educational institutions include urban planning, architectural-planning, natural-climatic, and aesthetic. The article also presents the brief analysis of architectural projects done abroad and at the Theory of Architecture Department of Kyiv National University of Construction and Architecture to illustrate the impact of factors and to show main trends of architectural development of modern educational buildings..

Streszczenie

W artykule określono główne elementy dotyczące wewnętrznych i zewnętrznych czynników, wpływających na rozwój architektury pozaformalnych instytucji edukacyjnych. Czynniki zewnętrzne reprezentowane są przez grupę czynników społeczno-ekonomicznych, czynnik techniczny (technologiczny), szereg czynników politycznych i czynnik środowiskowy. Czynniki wewnętrzne, które wpływają na rozwój architektury instytucji edukacyjnych, obejmują planowanie urbanistyczne, architektoniczne, przyrodniczo-klimatyczne i estetyczne. W artykule przedstawiono również krótką analizę projektów architektonicznych wykonanych za granicą oraz w Katedrze Teorii Architektury Kijowskiego Narodowego Uniwersytetu Budownictwa i Architektury w celu zilustrowania wpływu czynników i ukazania głównych trendów rozwoju architektonicznego nowoczesnych budynków edukacyjnych.

LUONG MINH CHINH

ANALYSIS AND ASSESSMENT OF EXISTING STRUCTURAL HEALTH MONITORING SYSTEMS (SHMS) OF CABLE-STAYED BRIDGE IN VIETNAM

ANALIZA I OCENA ISTNIEJĄCYCH SYSTEMÓW MONITOROWANIA STANU STRUKTURALNEGO (SHMS) MOSTU WANTOWEGO W WIETNAMIE

Structure and Environment No. 3/2019, vol. 11, p. 190 DOI: 10.30540/sae-2019-014

Abstract

Since 2000 when the My Thuan Bridge, the first cable-stayed bridge in Vietnam, was put into operation, and now Vietnam has more than 20 types of cable-stayed bridges constructed throughout the country in the last two decades, which is a significant accomplishment for a developing country like Vietnam. Therefore, the SHM system is gradually being designed and installed for cable stayed bridges to ensure economic exploitation and safety. Due to the limited of financing sources, these systems are very limited, and their quality have a lot to be desired. Also, due to the lack of appropriate classification personnel with experience in the SHM system, these systems encountered a lot of problems. In this article author will deeply analyze the mistakes and problems of these SHM systems, which already exist in Vietnam, to find solutions for the future. Therefore, this will open up new prospects, new challenges and possibilities for the development of these systems in Vietnam in the near future.

Streszczenie

W 2000 roku oddano do użytku most My Thuan, pierwszy most wantowy w Wietnamie, a teraz Wietnam ma ponad 20 rodzajów mostów wantowych zbudowanych w całym kraju w ciągu ostatnich dwóch dekad, co jest znaczącym osiągnięciem dla kraju rozwijającego się, takiego jak Wietnam. W związku z tym system SHM jest stopniowo projektowany i instalowany dla mostów kablowych, aby zapewnić ekonomiczną eksploatację i bezpieczeństwo. Ze względu na ograniczone źródła finansowania systemy te są bardzo ograniczone, a ich jakość pozostawia wiele do życzenia. Ponadto z powodu braku odpowiedniego wykwalifikowanego personelu z doświadczeniem w systemie SHM systemy te napotkały wiele problemów. W tym artykule autor dogłębnie przeanalizuje błędy i problemy systemów SHM, które już istnieją w Wietnamie, aby znaleźć rozwiązania na przyszłość. Otworzy to nowe perspektywy, nowe wyzwania i możliwości rozwoju tych systemów w Wietnamie w najbliższej przyszłości.

MICHAIL VASILEVICH NEMCHINOV
ANNA GENNADIEVNA IVANOVA

DECREASING THE HEIGHT OF MOTOR ROAD EMBANKMENTS BY CHANGING THE PRINCIPLE OF WATER FLOW AND SNOW PROTECTION IN THESE CONDITIONS

ZMNIEJSZENIE WYSOKOŚCI NASYPÓW SAMOCHODOWYCH POPRZEZ ZMIANĘ ZASADY PRZEPŁYWU WODY I OCHRONY PRZED ŚNIEGIEM

Structure and Environment No. 3/2019, vol. 11, p. 201 DOI: 10.30540/sae-2019-015

Abstract

The article puts forward a new type of culverts in roads. Main motive behind the construction of the new type of culverts is presented and examined: considerable height of road-beds at their construction locations and, as a result, unreasonably high road embankments. Snow drifts at roads and possible protection means are also examined. A report on theoretical analysis of the reasons of snow drifts experimental study with road models is included. The model showed low and high drifts blowing at different speeds at roads with and without embankments and with and without a snow-retaining barrier. All experiments were first conducted without cars on the traffic-bearing surface of the road, then with cars. Recommendations regarding road protection against snow are given.

Streszczenie

Artykuł przedstawia nowy typ przepustów na drogach. Przedstawiono w nim i zbadano główny motyw budowy nowego typu przepustów takie jak: znaczna wysokość koryt w ich miejscach budowy i ich konsekwencja w świetle nieuzasadnionych wysokich nasypów drogowych. Badane zostały również zaspy śniegu na drogach i możliwe środki ochrony. Uwzględniono raport z teoretycznej analizy przyczyn na podstawie eksperymentalnych badań nad zaspami śnieżnymi wykorzystując modele drogowe. Niniejszy model pokazał niskie i wysokie zaspy z uwzględnieniem wiatrów wiejących z różnymi prędkościami na drogach z nasypami i barierami przeciwśnieżnymi oraz przypadek bez nich. Wszystkie eksperymenty przeprowadzono najpierw bez samochodów na nawierzchni drogowej, a następnie z samochodami. Podano przedstawiono zalecenia dotyczące ochrony dróg przed śniegiem.

GNIESZKA WDOWIAK
JANUSZ BROL

METHODS OF STRENGTH GRADING OF STRUCTURAL TIMBER – COMPARATIVE ANALYSIS OF VISUAL AND MACHINE GRADING ON THE EXAMPLE OF SCOTS PINE TIMBER FROM FOUR NATURAL FOREST REGIONS OF POLAND

METODY SORTOWANIA WYTRZYMAŁOŚCIOWEGO TARCICY KONSTRUKCYJNEJ – ANALIZA PORÓWNAWCZA SORTOWANIA WIZUALNEGO I MASZYNOWEGO NA PRZYKŁADZIE POLSKIEJ TARCICY SOSNOWEJ Z CZTERECH KRAIN PRZYRODNICZO-LEŚNYCH

Structure and Environment No. 3/2019, vol. 11, p. 210 DOI: 10.30540/sae-2019-016

Abstract

The article covers the strength grading system methodology for construction timber. The presented analysis identified important issues concerning the verification of structural and geometric characteristics during construction timber strength grading by visual and machine method. The following considerations specified the guidelines for the classification of coniferous construction timber in sawmills. The paper also presents the results of the visual and machine classification performed for Scots pine timber from four natural forest regions of Poland. As a result of the conducted research it was stated that the use of machine classification equipment allows obtaining a larger amount of pine timber with better mechanical properties and eliminating the rejected timber.

Streszczenie

Artykuł obejmuje metodykę sortowania wytrzymałościowego dla tarcicy konstrukcyjnej. Przedstawiona analiza określiła ważne zagadnienia dotyczące weryfikacji cech strukturalnych i geometrycznych w trakcie sortowania wytrzymałościowego tarcicy konstrukcyjnej metodą wizualną oraz metodą maszynową. Poniższe rozważania skonkretyzowały wytyczne służące klasyfikacji tarcicy konstrukcyjnej iglastej w tartakach. W pracy ukazano również wyniki badań klasyfikacji wizualnej i maszynowej sosnowej tarcicy konstrukcyjnej pochodzącej z czterech krain przyrodniczo-leśnych Polski. W efekcie przeprowadzonych badań stwierdzono, że wykorzystanie urządzeń do klasyfikacji maszynowej umożliwia uzyskanie większej ilości sztuk tarcicy sosnowej o lepszych właściwościach mechanicznych oraz zniwelowanie liczebności tarcicy odrzuconej.

ANATOLIY PAVLENKO
ANNA MARIA SLOWAK

PHYSICO-CHEMICAL CHARACTERISTICS OF FUEL GAS MIXTURES

CHARAKTERYSTYKA FIZYKOCHEMICZNA MIESZANEK GAZÓW PALIWOWYCH

Structure and Environment No. 3/2019, vol. 11, p. 227 DOI: 10.30540/sae-2019-017

Abstract
The article presents data on changes in physical and chemical properties of mixtures of generator gases with natural gas and the issue of the optimal ratio of these gases in the mixture. The results of research on the basic properties of flammable mixture of generator gases and natural gas are presented, on the basis of which the optimal composition of the mixture was proposed.

Streszczenie
W artykule przedstawiono dane dotyczące zmian właściwości fizycznych i chemicznych mieszanin gazów generatorowych z gazem ziemnym oraz zagadnienie optymalnego stosunku tych gazów w mieszaninie. Przedstawiono wyniki badań podstawowych właściwości palnych mieszaniny gazów generatorowych i gazu ziemnego, na podstawie których zaproponowano optymalny skład mieszaniny.

Uniform requirements for manuscripts submitted to "Structure and Environment"

All manuscripts should be submitted in English and Polish.

Given name(s) and surname(s) of each author
Institutional affiliation(s)
Author's e-mail

Title

Format for the paper:
– Abstract
– Keywords
– Introduction
– Subsequent headings
– Summary
– References

The text should be single-spaced throughout. The font should be 11 pt Times New Roman. All paragraphs should be indented 0.5 cm.

Formulas, tables, figures and photographs should be numbered consecutively

Figures and photographs with a resolution of 300 dpi or higher must be submitted in *.TIFF, *.EPS, *.JPG, *.WMF format.

Figures, photographs and tables should be in English, but their captions should be given in English and Polish.

References: The paper submitted for publication must comply with copyright law provisions. Authors have to document sources of the photographs, figures, quotes and borrowings used in the article. References should be cited in square brackets through the text. The full list of references arranged in the citing order as they appear in the text should be placed at the end of the paper (with one language version only). The reference style is defined by the standard PN-ISO 690:2012 Information and documentation. Guidelines for bibliographic references and citations to information resources.

Examples

Whole books

[1] Author's surname followed by the initials: Title of the book. Place of publication: Publisher, Year of publication, ISBN number.

Edited books

[2] Surname and initials of the editor (Ed.): Title of the book. Place of publication: Publisher, Year of publication, ISBN number.

Chapters in edited books

[3] Author's surname followed by the initials: Title of the charter. (in): Title of the book. Place of publication: Publisher, Year of publication, page numbers (for example: pp. 10-20), ISBN number.

Journal articles

[4] Author's surname followed by the initials: Title of the article. "journal title" Year, Number, page numbers (for example: pp. 10-20), ISSN number

Web references

[5] Author's surname followed by the initials: Title of the work. [type of the source, for example: online]. [date when the reference was last Accessed: …]. Available online: web page

Podstawowe wymagania edytorskie dotyczące pisania artykułów do czasopisma „Structure and Environment"

Artykuł powinien być napisany w dwóch wersjach językowych: angielskiej oraz polskiej.

Imię i nazwisko autora
Nazwa uczelni
e-mail autora

Tytuł artykułu

Struktura artykułu:
– Streszczenie
– Słowa kluczowe
– Wprowadzenie
– Kolejne podtytuły
– Podsumowanie
– Bibliografia

Tekst artykułu powinien być napisany czcionką Times New Roman 11, interlinia pojedyncza, wcięcie akapitowe 0,5 cm.

Wzory, tabele, rysunki oraz zdjęcia powinny być ponumerowane zgodnie z kolejnością ich występowania w tekście.

Rysunki oraz zdjęcia o rozdzielczości 300 dpi lub wyższej, format *.TIFF, *.EPS, *.JPG, *.WMF.

Rysunki, zdjęcia oraz tabele zamieszczamy w wersji angielskiej, a ich tytuły podajemy zarówno w języku angielskim, jak i języku polskim.

Bibliografia: Artykuł przeznaczony do publikacji musi być przygotowany zgodnie z postanowieniami ustawy „Prawo autorskie", które nakłada na autora obowiązek wykazania źródeł wykorzystanych zdjęć, rysunków cytowań, zapożyczeń. Źródła takie należy umieszczać w tekście w nawiasach kwadratowych. Zbiorcze zestawienie bibliografii umieszczamy na końcu artykułu w kolejności cytowania (tylko przy jednej wersji językowej).

Styl bibliograficzny definiuje norma: **PN-ISO 690:2012** *Informacja i dokumentacja. Wytyczne opracowania przypisów bibliograficznych i powołań na zasoby informacji*.

Przykłady

Pozycje książkowe
[1] Nazwisko i inicjały imion autora: *Tytuł: podtytuł*. Miejsce wydania: Wydawca, Rok, Numer ISBN.

Praca zbiorowa
[2] Nazwisko i inicjały imion redaktora (red): *Tytuł: podtytuł*. Miejsce wydania: Wydawca, Rok, Numer ISBN.

Rozdziały książek
[3] Nazwisko i inicjały imion autora: *Tytuł: podtytuł rozdziału*. [w]: *Tytuł publikacji*. Miejsce wydania: Wydawca, Rok, Strony (np. s. 10-20), Numer ISBN.

Artykuły w czasopismach
[4] Nazwisko i inicjały imion autora: *Tytuł artykułu*. „Tytuł czasopisma" Rok, Numer, Strony (np. s. 8-27), Numer ISSN.

Strony internetowe
[5] Nazwisko i inicjały imion autora: *Tytuł*. [typ nośnika (np. online)]. [data dostępu: ...]. Dostępny w internecie: Adres strony internetowej

THE REVIEW PROCESS

The following requirements need to be met by the paper:
– the title should reflect the content of the paper
– the content should be within the thematic scope of the journal
– the paper should be properly and clearly divided into paragraphs
– original elements need to be part of the paper
– the research method should be properly selected
– adequate references need to be cited
– interpretation and conclusions should match the presented test results
– the paper should not contain parts indicating commercial use