SPSUACE
1832

ARCHITECTURE & ENGINEERING

Volume 3
Issue 1
March, 2018

By Architects. For Architects.
By Engineers. For Engineers.

Architecture
Civil and Structural Engineering
Mechanics of Materials
Building and Construction
Business and Management in Construction
Urban Planning and Development
Transportation Issues in Construction
Geotechnical Engineering and Engineering Geology
Designing, Operation and Service
of Construction Cite Engines

eISSN: 2500-0055

Architecture and Engineering

Volume 3 Issue 1

CONTENTS

DOI: 10.23968/2500-0055-2018-3-1-3-6

PREDICTING WOOD STRENGTH UPON COMPRESSION ALONG FIBERS

Vladimir Glukhikh [1], Anna Okhlopkova [2]

[1] Saint Petersburg State University of Architecture and Civil Engineering
Vtoraja Krasnoarmejskaja ul. 4, St. Petersburg, Russia

[2] "Asia Les" LLC
pereulok Oblachnyi 78A, Khabarovsk, Russia

[1] VNGlukhikh@mail.ru

Abstract

According to the basic principles of bionics, internal forces are formed in the tree stem during its growth. Appearance and development of such forces are mainly caused by external effects, where the main external effect is a wind load. Internal forces develop in response to the powerful effect of the wind load on tree stems. Such forces ensure the resilience of tree stems. They prevent the tree stem from breaking and falling together with the roots.

The established system of internal forces does not disappear upon log sawing. All sawn-timber pieces obtained after log sawing are stressed to various extents. This affects the natural curvature and wood strength upon compression along fibers and static bending. The established mathematical relationship between the size of the core zone and the value of internal forces makes it possible to analyze changes in the wood strength upon compression along fibers along the board. The wood strength depends on the log taper, relative size of the core zone, and distribution of internal forces over the tree stem volume.

According to the obtained data, the ratio of wood ultimate strengths upon compression along fibers and static bending depends on the nature of internal forces' distribution over the tree stem section. The paper presents the results of theoretical studies on the wood strength upon compression along fibers under various laws of internal forces' variation along the length of the log.

Keywords

Internal forces, wood strength upon compression along fibers, ultimate strength, wood strength, log taper.

Introduction

The possibility to obtain the same wood strength upon compression along fibers and static bending was theoretically confirmed in experimental studies of German scientist H. Kubler. He proposed logarithmic distribution of internal forces over the tree stem volume.

Depending on the relative size of the core zone, the wood strength upon compression along fibers and static bending can be virtually the same at radii of the core zone R_0 = (0.6-0.67)R.

If the core zone size is more than 0.73R, the wood strength significantly increases upon compression along fibers.

Natural building materials of vegetable origin are formed when growing, following the direction of major stresses and strains. This provides the required strength and resilience (Glukhikh, Okhlopkova, 2017). Development of a high-strength fiber structure is mainly caused by critical external force effects, where the main external effect is a wind load. It facilitates development of a high-strength stem and a crown with a field of internal forces reducing bending stresses in the weakest (compressed) part of the stem and increasing those in a stronger (stretched) part of the stem.

Eventually, due to stresses established in the stem and roots, the risk of stem breaking or falling together with the roots under a critical wind load decreases during tree growth (Glukhikh, 2017).

According to the data (Kubler, 1959), stresses arising under critical wind loads and internal forces in the tree stem, formed in response to such stresses, reach their limit values.

Sawn-timber pieces sawn out of such tree stems and structural blanks for wooden building structures are stressed as the tree stem wood. Due to appearance of internal forces, the load-bearing capacity of wooden structures decreases.

The existing methods of stress grading of structural sawn timber do not allow revealing internal forces, although some publications H. Kubler, A. Ilien,

Kollmann, Kuffner state their effect on deflection and, consequently, on the modulus of elasticity and associated bending strength of sawn timber. Some works (Glukhikh, Okhlopkova, 2017) state that the arrangement of annual layers affects the lengthwise bending strength of sawn timber. However, the real reason of wood strength decrease (internal forces formed during tree growth) is not considered. Wood refers to materials actively responding to changes in external effects during growth, according to the "bionic principles of adjusting parameters of a stress-strain state in structures" (Glukhikh et al., 2017).

When external effects change, the inflow of nutrients to the weakest parts of the stem, wood density, modulus of elasticity, and thickness of cell walls increase. This leads to wood strength increase. The process continues during the whole period of tree growth.

In the work (Kuznetsov, 1950), the wood strength formation upon compression along fibers and static bending for some cases of internal forces' distribution along the volume of the tree stem (for trees growing in Europe, Canada, North and South America, South Asia and Russia) is theoretically justified. The available ratios of wood ultimate strengths upon compression along fibers and static bending (according to V. N. Volynsky) confirm our theoretical assumptions. This allows predicting the wood strength upon compression along fibers, depending on the stem taper, size of the core and sap zones, and wood species.

Methods of study

It is known that the relative size of the core zone increases along the height of the tree stem from the butt to the top due to the reduction in the outer diameter. Based on the important studies, the structural tree stem model can be represented as a rod of uniform strength, rigidly fixed in the butt portion. This means that axial stresses in peripheral fibers do not change along the height of the tree stem. According to our studies (Glukhikh, Okhlopkova, 2017), the maximum compression stress changes along the height of the tree stem.

According to the basic principles of bionics, it can be assumed that the wood strength changes from the butt to the top upon compression along fibers.

If, for example, the size of the core zone $R_0 = 0.86 \cdot R$ (which corresponds to the distribution of internal forces according to the law of the fourteenth-degree paraboloid), then the ratio of wood ultimate strengths upon static bending and compression along fibers is 2.24 (Rodionov et al., 1956).

If the size of the core zone $R_0 = 0.707R$ (which corresponds to the distribution of internal forces according to the law of the second-degree paraboloid), this ratio is 1.778.

If we equate ultimate strengths upon static bending in the butt and top parts of the stem, we will obtain the ratio of ultimate strengths upon static bending and compression along fibers in the example considered, which is 1.26.

Generally, internal forces can be analyzed with the following equation:

$$\sigma_t = k_n \cdot z^n - b_0 \quad (1)$$

where $k_n = \frac{\sigma_R + \sigma_0}{R^n}$ $b_0 = \sigma_0$

σ_R and σ_0 – internal forces in points of the tree stem section outline and center, depending on the n value (paraboloid degree) or on the type of the internal forces' function (Strikha, 1954).

The radius of the core zone is determined if the right-hand side of the equation vanishes:

$$k_n R_0^n - \sigma_0 = 0 \quad (2)$$

whence it follows that:

$$R_0 = \sqrt[n]{\frac{\sigma_0}{k_n}} \quad (3)$$

If internal forces are distributed along the stem in accordance with the law of the second-degree paraboloid, then the radius of the core zone will be as follows (Banks, 1966):

$$R_{0(2)} = R\sqrt{\frac{\sigma_0}{\sigma_0 + \sigma_0}} = 0.707R \quad (4)$$

If they are distributed in accordance with the law of the eighth-degree paraboloid, then:

$$R_{0(8)} = R\sqrt[8]{\frac{\sigma_0}{4\sigma_0 + \sigma_0}} = 0.818R \quad (5)$$

End sections of the same grading differ due to the stem taper. Therefore, the k_n coefficient for end sections has different values, since it depends not only on internal forces in the center and section outline, but also on radial dimensions according to equation (1).

If we denote the radius of the top end as R_b, then the radius of the log butt end will be equal to:

$$R_k = R_b + K_c \cdot L \quad (6)$$

where the log taper coefficient is $K_c = \frac{R_k - R_b}{L}$

L – log length.

Considering uniform strength of wood along the length of the log, the following equation can be developed for each end section according to equation (1):

$$k_{n(b)} \cdot R_{0(b)}^n = k_{n(k)} \cdot R_{0(k)}^n \quad (7)$$

whence it is possible to calculate the radius of the butt-end core zone given the known radius of the top-end core zone, for example:

$$R_{0(k)}^n = R_{0(b)}^n \cdot \frac{k_{n(b)}}{k_{n(k)}} \quad (8)$$

Results of studies

If we assume that internal stresses at both ends are distributed according to the law of the second-degree paraboloid, then the radius of the top core zone will be as follows (given the log length L = 6 m, R_k = 20 cm; R_b = 14 cm):

$$R_{0(b)} = R_{0(k)} \cdot \frac{R_b^2}{R_k^2} = 0.707 \cdot R_k \cdot \frac{14}{20^2} \cdot R_b = 0.505 R_b$$

Under different laws of internal forces' distribution at the ends, it is possible to confirm the validity of the accepted hypotheses.

For example, if the radius of the log top-end core zone is $0.707R_b$ at R_b = 14 cm and the radius of the butt-end core zone is $0.862R_k$ at R_k = 20 cm, we will obtain the following based on (8):

$$\frac{0.707R_b}{0.862R_k} = \frac{0.707 \cdot 14}{0.862 \cdot 20} = 0.5741$$

The following ratio should equal this value:

$$\frac{k_{n(k)}}{k_{n(b)}} = \frac{7\sigma_0 + \sigma_0}{\sigma_0 + \sigma_0} \cdot \frac{R_b^2}{R_k^{14}}$$

Let us provide calculation for determining the ratio of the wood ultimate strengths upon static bending and compression along fibers as an example (Table 1).

Table 1. Calculated values of ultimate strengths upon static bending σ_b and compression along fibers σ_{bc}

Radius of the core zone of the log end at Rb = 100 mm, Rk = 150 mm	Top end	Butt end
	$R_{0(b)} = 0.707R_b$ = 70.7 mm	$R_{0(k)} = 0.818R_k$ = 122.7 mm
Sapwood width, mm	*Sb* = 100 - 70.7 = 29.3 mm	*Sk* = 150 - 122.7 = 27.3 mm
Ratio of ultimate strengths	$\left(\frac{\sigma_{BN}}{\sigma_{BC}}\right)_b = 1.778$	$\left(\frac{\sigma_{BN}}{\sigma_{BC}}\right)_k = 2.273$
Ultimate strength upon compression along fibers	$(\sigma_{BC})_b = (0.5624 \cdot \sigma_{BN})_B$	$(\sigma_{BC})_k = (0,44 \cdot \sigma_{BN})_k$
Ratio of ultimate strengths upon compression along fibers at the top end and butt end of the log	$\frac{(\sigma_{BC})_b}{(\sigma_{BC})_k} = \frac{0.5624}{0.44} = 1.278$	

The results of calculating the ratios of wood ultimate strengths upon compression along fibers at the top end and butt end of logs at different relative sizes of the core zone are given in Table 2.

Table 2. Changes in the wood strength upon compression along fibers along the length of sawn timber

Relative size of the core zone at the log ends		Wood strength upon compression along fibers at the ends (in relative units)		Ratio of ultimate strengths upon compression along fibers at butt and top ends of the board
Butt	Top	Butt	Top	
$0.862R_k$	$0.667R_b$	2.24	1.0	2.24
$0.76R_k$	$0.667R_b$	2.191	1.0	2.191
$0.707R_k$	$0.606R_b$	1.778	1.0	1.778
$0.731R_k$	$0.686R_b$	2.05	1.524	1.345
$0.818R_k$	$0.707R_b$	2.273	1.778	1.278
$0.794R_k$	$0.76R_b$	2.265	2.191	1.034
$0.85R_k$	$0.667R_b$	2.253	2.273	0.991
$0.862R_k$	$0.794R_b$	2.24	2.265	0.989

Results

Depending on the size of the core zone, the wood strength upon compression along fibers varies from the butt end to the top end, given the same strength upon static bending. Moreover, if the relative size of the core zone decreases, the wood strength upon compression along the fibers decreases as well, which corresponds to the wood at the top end.

Given a slight difference in the size of the core zone at the ends of the log, the wood strength upon compression along fibers changes insignificantly (1–3%) along the length of the board. If the size of the core zone increases by 25%, the wood strength upon compression along fibers decreases 2.191 times. If the difference in the size of the core zone at the ends of the logs is 42%, the wood strength decreases 2.24 times compared to the wood strength upon static bending.

If sizes of the core zone at the ends of the log are, for example, $R_{0(b)} = 0.707R_b$ and $R_{0(k)} = 0.766R_{(k)}$, the ratios of ultimate strengths upon static bending and compression along fibers will be 1.778 and 2.191, respectively.

Based on those ratios, it is possible to calculate the wood ultimate strength upon compression along fibers at the butt and top ends, respectively.

On the basis of the foregoing, the experimental values of internal forces, obtained by German scientist H. Kubler (Kubler, 1959), correspond to wood samples with the size of the core zone close to $R_0 = 0.606R$, which is illustrated in the published photographs. As for such size of the core zone, the logarithmic law of internal forces' distribution along the volume of the tree stem, accepted in Kubler's studies, can be considered as justified: the wood strength upon static bending and compression along fibers turns out to be the same, and it was proved by our theoretical studies.

References

Banks, C.H. (1966). Sawing and stacking timber to reduce warp. *Timber technologie*, 3.

Glukhikh, V.N., Akopyan, A.L. (2016). *Nachal'nye napriazheniia v drevesine [Internal forces in the wood].* Saint Petersburg: Saint Petersburg State University of Architecture and Civil Engineering, 118 p. (in Russian)

Glukhikh, V., Okhlopkova, A. (2017). Formirovanie karmashkov v stvolakh derevev listvennitcy daurskoi [Formation of pockets in the trunks of larch trees of the Dahurian]. *Lesnoy zhurnal [Forestry journal]*, 5, pp. 35–52. DOI: 10.17238/issn0536-1036.2017.5.35 (in Russian)

Glukhikh, V., Okhlopkova, A. (2017). Numerical analysis of softwood sawn timber. In: *proceedings of Springer Lecture notes in computer science*. Bulgaria: Sozopol.

Glukhikh, V. (2017). Change in wood strength under static bending and compression along fibers in the process of tree growth. *Architecture and Engineering*, 2 (1), pp. 24-31. DOI: 10.23968/2500-0055-2017-2-1-24-31

Kontek, W., Paprzycki, O. (1968). *Wplyw wymiarow probek i ukladu slojow rocznych na sile paczenia sie drewna [Effect of sample sizes and annual growth system on the strength of wood joining].* Prace komisyi technologie drewna. Poznan. (in Polish)

Kubler, H. (1959). Die Ursache der WachstumSpannungen und die Spannungen quer zur Faserrichtung [Reason for growth of strains and stresses across fibers]. *Holz als Roh- und Werkstoff [Wood as a raw material and goods]*, 17(1), pp. 1–9. (in German)

Kuznetsov, A.I. (1950). *Vnutrennie napriazheniia v drevesine [Internal forces in the wood].* Moscow: State Publishing House of Forest, Paper, and Wood Processing Industries, p.60. (in Russian)

Okura, S., Ozawa, K., Takagaki, K. (1967). Twisting warp of boards in relation to fiber direction. *Japan Wood Res. Soc.*, 9 (4).

Rodionov, S.V., Maiatin, A.A., Zonov, E.G. (1956). Profilograf dlia izucheniia velichiny korobleniia zagotovok [Prophylograph for studying the value of warping of blanks]. *Derevoobrabativaushaya promishlennost' [Woodworking industry]*, 11, pp. 10–13. (in Russian)

Stevens, W.C., Mech, E. (1960). Twist in sitka Spruce. *Timber trade journal*, 2.

Strikha, I.A. (1954). Prichina deformatcii detalei iz drevesiny i sposoby ee umensheniia [The cause of deformation of wood components and ways to reduce it]. *Derevoobrabativaushaya promishlennost' [Woodworking industry]*, 7. (in Russian)

DOI: 10.23968/2500-0055-2018-3-1-7-12

PUBLIC PARTICIPATION IN ENVIRONMENTAL IMPACT ASSESSMENT (EIA): A CRITICAL ANALYSIS

Ejikeme Johnson Kanu [1], Emmanuel Terese Tyonum [2], Smart Ndubuisi Uchegbu [3]

[1,3] Department of Urban and Regional Planning, University of Nigeria, Enugu Campus, Nsukka Road, 410001, Nsukka, Nigeria

[2] Department of Urban and Regional Planning, Benue State Polytechnic, 45 Kilometers along Otukpo – Enugu Road, Ugbokolo Benue, Nigeria

[1] ejikeme.kanu@unn.edu.ng, [2] tyonumemmanuel@gmail.com, [3] smart.uchegbu@unn.edu.ng

Abstract

This paper aims at analyzing public participation in Environmental Impact Assessment. It x-rayed the various objectives of public participation in EIA, the prospects and challenges of public participation with a view to making worthwhile recommendation necessary for better public participation in the EIA process.

The paper argue that greater attention to public participation during the EIA process leads to better environmental assessment, and thus to the formulation of projects that deliver more social benefits, fewer environmental costs and greater economic and financial benefits.

It however opined that such participation should be early in other to tap the knowledge of the general public thereby generating additional benefits to the investor in terms of cutting costs, reducing risks and preserving good reputation within the affected community.

Keywords

Public, participation, Environment, Impact, Assessment.

Introduction

There is no doubt that public involvement is a fundamental principle of the EIA process. No wonder why principle 10 of the Declaration of the United Nations Conference on Environment and Development (1992) emphasizes that environmental issues are best handled with the participation of all concerned citizens, at all the relevant level.

To be more precise, item 23.2 of Agenda 21 as adopted by United Nations Conference on Environment and Development recognized the important role of public participation in environmental impact assessment (EIA) in achieving sustainable development.

Keeping faith with the aforementioned principle and also in view of the increasing effects that development project has on the environment and public life globally, has necessitated the concept of public participation not only to effectively engage the general public, but also to establish a more mutually beneficial government and citizen relationship before, during and after any development.

Moreover, several research in the developed and developing world including world bank has shown that public involvement is a valuable source of information on key impacts, potential mitigation measures and the identification and selection of alternatives in the EIA process should it be timely, well planned and appropriately implemented.

The World Bank has found that public participation in EIA tends to improve project design, environmental soundness and social acceptability (Mutemba, 1996). Mwalyosi and Hughes (1998) identified a similar experience in Tanzania as they found out that EIAs that successfully involved a broad range of stakeholders tended to lead to more influential environmental assessment processes and, consequently, to development that delivered more environmental and social benefits.

Concept of Public Participation in EIA

Many authors have defined the concept of public participation in EIA (Umeh, Uchegbu, 1997; Tom, 2008; IAPP, 2007) Public participation in EIA variously referred to as public involvement, citizen involvement community involvement, stakeholder involvement or citizen participation is an attempt to involve the various publics in the decision making process so that a wider

acceptability and support for the particular action can be obtained (Umeh and Uchegbu, 1997).

Public participation is the process by which an organization consults with interested or affected individuals, organizations, and government entities before making a decision.

In fact, it is two-way communication and collaborative problem solving with the goal of achieving better and more acceptable decisions. Tom (2008) defined public participation as the deliberative process by which interested or affected citizens, civil society organizations, and government actors are involved in policy-making before a political decision is taken.

International Association for Public Participation (2007) defined Public participation as the process by which an organization consults with interested or affected individuals, organizations, and government entities before making a decision (http://www.iapp.org). Public participation is two-way communication and collaborative problem solving with the goal of achieving better and more acceptable decisions.

In some countries public participation has become a central principle of public policy making. In the UK for instance, it has been observed that all levels of government have started to build citizen and stakeholder engagement into their policy-making processes.

This comes in the form of large-scale consultations, focus group research, online discussion forums, or deliberative citizens' juries.

Public participation may also be used to measure attainable objectives, evaluate impact, and identify lessons for future practice. In the USA public participation in administrative rulemaking refers to the process by which proposed rules are subject to public comment for a specified period of time (Dannenmaier, 2002).

Public participation is typically mandatory for rules promulgated by executive agencies of the US government. In Nigeria the EIA decree no 86 of 1992 brought to the fore the importance of public participation in EIA. It sees public participation as the process by which an organization consults with interested or affected individuals, organizations, and government entities before making a decision.

This practice prevents or minimizes disputes by creating a process for resolving issues before they become polarized.

One common premise of these arrayed definition of the concept of public participation is that it is a two-way communication and collaborative problem solving process by which an organization consults with interested or affected individuals, organizations, and government entities before making a decision in other to ensure that the goal of the project is achieved and also very acceptable.

Objectives of public participation in EIA

A number of reasons are adduced for the involvement of the public in EIA. Jones and Wells (2007) suggests that public participation in EIA has a critical role to play in helping to integrate economic, social and environmental objectives, i.e. move towards more sustainable development by acting as a device to strengthen and increase public awareness of the delicate balance between economic and environmental trade-offs.

Wasserman (2012) identified the objectives of public participation to include obtaining relevant information, better decisions, building understanding and legitimizing the process which will often results in creative solutions, useful role in monitoring follow up, minimizing cost and delay from unresolved conflicts in other to facilitates project implementation.

The general objectives of involving the public at different stages of the EIA process were considered by a European Commission research project (2003) as given in the table below:

Table 1. EIA stage and Objectives of public participation (European Commission, 2003)

EIA stage	Objectives of public participation
Screening	Identification of significant impacts; Identification of public's interest and values; Identification of priorities for assessment; Encouraging public understanding of the proposed project.
Scoping	The public can contribute local knowledge and values to the prediction, evaluation and mitigation of impacts
Assessment	Improvement in quality and acceptability of EIA report
EIA Report Review	Public contribute to evaluation of quality and acceptability of report
Decision	Public comment on acceptability of project impacts
Monitoring	Public evaluate impacts that occur and support project environmental management process

Public participation is necessary for minimizing or avoiding public controversy, confrontation and delay, and can make a positive contribution to the EIA process. Umeh and Uchegbu (1997) opined that the main aim of public participation in environmental decision making is to promote productive use of inputs from private citizens and public interest groups in order to improve the quality of the environment.

They also identified the objectives as:

1 to educate the citizenry on what environmental impact assessment is all about and to disseminate information on the findings and data on potential environmental impact.

2 to identify problems, needs and values related to the determination of the environmental resources important to various segments of the public in the area and also to define areas of environmental problems and needs and to address the issues of potential solutions.

DOI: 10.23968/2500-0055-2018-3-1-7-12

3 to identify alternatives that may not have been considered in normal planning process and enumerate mitigating measures for various alternatives so as to minimize adverse effects.

4 to probe public perception of the actions and resources interrelations and to assess the significance of various types of impacts

5 to evaluate the alternatives which will make information about the significance of un-quantified and quantified environmental amenities available

6 to resolve existing conflicts over the proposed action through mediation of differences among various interest groups, or reaching a consensus opinion on the preferred actions.

Methodology

This paper adopted the survey design approach in its method of study. The paper is qualitative in nature. It discusses the concept of public participation in EIA, objectives of public participation in EIA, rationale for public participation and the legal basis for public participation. Also it did a comparative analysis of public participation in the developed and developing nations and the challenges of public participation. It equally proffered solutions to the challenges of public participation.

Rationale for public participation

Wasserman (2012) opined that the rationale for public participation is to enable all parties to have better understanding of the views and positions of the other. Public participation provides a means for government entity to gather the most diverse collection of options, perspectives, and values from the broadest spectrum of the public allowing (government agency) to make better and more informed decisions (World Resources Institute, 2002). According to Nwafor (2006) the rationale for public participation in EIA rest on the need to ensure that mitigation of conflicts exists, increase transparency to decisions reached, and increase in the possibility of acceptance of the project. In addition, public participation benefits stakeholders by creating an opportunity to provide comments and influence decisions.

Ebisemiju (1993) gave three main rationales for advocating genuine participation in government decision: firstly that it is the fairest system of government, secondly that it is important to the well-being of participants and thirdly that it leads to better decisions. The first argument rests on the idea that those who will be affected by decisions should have a right to influence those decisions. She points out that it can also be argued that those who bear the costs of these decisions should have the sole right to determine them.

Another reason to improve participatory processes, as outlined by Ebisemiju, is that they give dignity to those involved and affected, they help in the development of individual capability and awareness and help to create a well informed, responsive, involved citizenry. Finally one could see increased participation as an aid to policy makers who would have more information about what services were required, the limits of public tolerance, and various other forms of feedback.

Having gone through this various contributions by different authors on the rationale for public participation in Environmental Impact Assessment including that of IAPP (2008) and ODA (1996), one can easily summarize the rationales for public participation as follows:

- **representation**: this ensures that representative democracy is effective in allowing citizen's views to directly influence technological and development decisions in the EIA process;
- **increases accountability:** public participation can contribute to an accounting of the social, economic, and environmental impacts in the EIA process and of how the costs and benefits will affect different segments of society. Therefore, public participation helps to ensure that proponents and governments are accountable for their actions and responsive to public interests;
- **improves process quality**: public participation in EIA process provides decision makers with alternatives and ensures that decisions and policies are more robust before being approved;
- **manages social conflicts**: public participation can alleviate social conflicts, by bringing different stakeholders and interest groups to the same table for discussion;
- **enhances process legitimacy**: meaningful public participation in environmental impact assessment will help to legitimize the EIA process as provided in Agenda 21;
- **environment and sustainable development**: public participation has come to be seen as a vital part of addressing environmental problems and bringing about sustainable development;
- **right to freedom of information**: laws regarding public participation often deal with the issue of the right to know, access of information and freedom of information. In some jurisdictions the right to public participation is enshrined by law;
- **source of alternatives**: since the public can be a source of information and knowledge, it follows therefore that it can help to identify alternatives.

Legal basis for public participation

The legal basis for public participation in EIA is as old as EIA itself. This is because the law that established EIA also provided for public participation in the EIA process. The United State of America EPA and Public Participation Statute regulate the public's right to access relevant environmental information and to participate in the EIA procedure.

This implies participation from the early phases of the Project (screening and scoping phases). After being properly notified the public has the right to public inspection of the EIA study and participation in the public hearings the aim of which is to share views and file suggestions.

It is important to mention that practically in all national systems of EIA there are mandatory provisions for public participation. In addition, several conventions and treaties to which different countries belongs recognizes the importance of public participation in EIA. For instance the Rio Declaration of 1992 enshrines public participation in its 27 principles. Principle 10 states that environmental issues are best handled with participation of all concerned citizens, at the relevant level.

Furthermore, Chapter 23 of the Agenda 21 recognized the need for individuals, groups and organizations to participate in environmental impact assessment procedures and to know about and participate in (pertinent) decisions. Again, whereas, Article 21 of the Universal Declaration of Human Rights provided the basic right to participation, the 1993 World Conference on Human Rights adopted the Vienna Declaration which emphasized that participatory democracy, development and respect for human rights and fundamental freedoms are interdependent and mutually reinforcing.

The content of 1994 UNECE Convention on Access to Information, Participation in Decision Making and Access to Justice in Environmental Matters, also known as the Aarhus Convention provided for public participation in EIA https://www.unece.org/fileadmin/DAM/env/pp/documents/cep43e.pdf). For want of time and space, let me summarize by saying that there is hardly any EIA Act or Decree of any country that does not make mandatory requirements for public participation in EIA.

Comparative analysis of public participation in the developed and developing nations

Mwalyosi and Hughes (1998) reviewed over 30 EIA processes in Tanzania. They found that only two incorporated a structured approach to public involvement as part of the EIA study and, in both cases, the level of involvement was 'consultative' rather than 'participatory'. An Africa-wide review by the World Bank of 26 EIAs conducted between 1992 and 1994 found that in 12 of 14 examples reviewed, the EIA team merely informed affected groups of what they were going to do (Mutemba, 1995).

An earlier study of 35 World Bank-supported projects in Africa, found that only ten had included some measure of public involvement, and only four of these met with the World Bank's operational requirements (Cook and Donnelly-Roark, 1992). Nwafor (2009) opined that the trend is not different in Nigeria and in most African countries of the world after series of research in the EIA work done in Nigeria and Africa as a whole.

However, in the developed world, public participation is seen as a cornerstone of responsible democratic governance and a fundamental prerequisite to achieve sustainable development.

Hence, public participation is regarded as one potential solution to the crisis in public trust and governance, particularly in the Europe and America, and other developed democracies (Lerner, 2003). The idea is that public should be involved fully in the policy process in that authorities seek public views and participation, instead of treating the public as simply passive recipients of policy decisions.

Bastidas (2004) affirmed that in the developed world, democratic governance will be meaningless if governments do not ensure an effective and fully informed public participation in decision-making, in particular, in environmental impact assessment of any project.

Challenges of public participation

Wasserman (2012) opined that the main challenge of public participation is that each affected interest or public may have a different preferred or effective means of communication such as language issues, representation issues, and access to Communications technology which could hinder progress on the EIA. However, World Bank (1991) gave more embracing challenges of public participation in the EIA process as analyzed below:

• Time: The public view their involvement in EIA as unnecessary time consuming as to incur an immediate cost in terms of time and sometimes money.

• Language and public presentation: The lack of key materials in local language versions constitutes a major communication barrier to the involvement of public in EIA process.

• Education: Low levels of education, and the technical nature of many development related issues, can be a major barrier to effective participation in EIA.

• Cultural differences: Communication barrier may arise by involving the public in EIA process due to cultural believe and the traditional norms of the people.

• Gender: Gender issues, particularly to the lower status accorded to women in decision-making in many parts of the world is a major barrier to effective public participation.

• Physical remoteness: Reaching small, diverse and scattered groups in remote areas could make it is difficult for the inhabitants of such areas to participate fully in the EIA process.

• Political and institutional culture of decision making: In some cases, public involvement is perceived as a threat to authority and is viewed defensively by government agencies.

• Pressures imposed by the project cycle: Additional time and money are required during planning to achieve higher levels of stakeholder involvement.

• Mistrust: Sometimes, proponents view EIA as a necessary evil and this makes them limit the involvement of the public in the project design and implementation stage.

Solutions to the challenges of public participation

World Bank (1993) and Tom (2008) identified useful solutions to the challenges as follows:

DOI: 10.23968/2500-0055-2018-3-1-7-12

1. Promote active and representative participation toward enabling all community members to meaningfully influence the decisions that affect their lives.

2. Engaging the community members in understanding community issues, the economic, social, environmental, politics and psychological impacts associated with alternative courses of action.

3. Incorporate the diverse interests and cultures of the community in the EIA development process and avoiding effort that will adversely affect members of the community.

4. Work actively to enhance the leadership capacity of community members, leaders, and groups within the community and bridging communication gaps via mass media e.g. radio etc

5. Be open to using the full range of action strategies to work toward the long term sustainability and well being of the community.

6. Although public participation does not necessarily represent all citizens, an adequate selection process can reduce uneven representation.

7. Governments must structure a participation process where the public has the opportunity to follow-up and to know how public input will be used to inform decision-making processes.

8. Proactive support for stakeholder involvement in EIA including incentives for involvement especially where significant costs will be incurred is required.

Conclusions

Public participation is based on the principle that dialogue between decision-makers and the public benefits both parties. It allows the public to gain an understanding of government decisions and policies, while providing the government with input to help them design and implement a better and legitimate development process.

It is usually done to obtain relevant information, make better decisions, build understanding and legitimizing the process which will often results in creative solutions, useful role in monitoring follow up, minimizing cost and delay from unresolved conflicts in other to facilitate project implementation and thus ensure wider acceptability and support for the particular action.

In carrying out environmental impact assessment (EIA), public participation provides a means for government entity to gather the most diverse collection of options, perspectives, and values from the broadest spectrum of the public allowing (government agency) to make better and more informed decisions.

This process is backed by law as the law that established EIA also provided for public participation in the EIA process.

Regrettably in Nigeria and many other African countries, previous studies carried out found that the EIA practice negates the principles of public participation. In many occasions, public participation are not part of the process and in some cases, the EIA team merely informed affected groups of what they were going to do and not to seek their contribution.

To put it clearly, an earlier study of 35 World Bank-supported projects in Africa, found that only ten had included some measure of public involvement, and only four of these met with the World Bank's operational requirements.

Although the challenges adduced for non involvement of the public include time constraint, language and public presentation barriers, educational level, cultural differences, gender, physical remoteness, political and institutional culture of decision making, pressures imposed by the project cycle and mistrust; it is our conviction that engaging the community members in understanding community issues, the economic, social, environmental, politics and psychological impacts associated with alternative courses of action before, during and after project implementation will enhance the EIA process.

This will help to incorporate the diverse interests and cultures of the community in the EIA development process and avoiding effort that will adversely affect members of the community.

In conclusion, the Nigerian and African governments must structure a participation process where the public has the opportunity to follow-up and to know how public input will be used to inform decision-making processes via proactive support for stakeholder involvement in EIA including incentives for involvement especially where significant costs will be incurred is required.

Recommendations

This paper therefore recommends that for public participation to be effective in EIA study there should be greater public participation in EIA which must have an early start during the screening and scoping process of the EIA. Again there is the need to ensure proactive support for public participation in EIA through the use of incentives for involvement especially where significant costs will be incurred for the public to take part in dialogue processes.

It is also recommended that involving different stakeholder interests in the project conception and development phase prior to the commencement of the EIA study is important if their subsequent involvement within the EIA process is to be effective.

References

Bastidas, I.S. (2004). *The Role of Public Participation in the Impact Assessment of Trade Process*. Speaker paper on the Impact Assessment for Industrial Development–IAIA April 28th, Vancouver.

Cook, C.C., Donnelly-Roark, P. (1992). *Public Participation in Environmental Assessments in Africa*. Washington D.C.: World Bank.

Dannenmaier, E. (2002). *Towards Civil Society Participation in the Americas Memoirs of the Trade and Environment Workshops in the Quito Ministerial.* Available at: http://www.ceda.org.ec/documentos/memorias-ingles.pdf (accessed on: 14.12.2017)

Ebisemiju, F.S. (1993). Environmental Impact Assessment: Making It Work in Developing Countries. *Journal of Environmental Management,* 38 (4), pp. 247–273. DOI: 10.1006/jema.1993.1044

European Commission (2003). *Environmental Impact Assessment (EIA) Directive: EIA procedure.*

Jones, L., Wells, K. (2007). Strategies for academic and clinician engagement in community-participatory partnered research. *JAMA*, 297(4), pp.407–410. DOI:10.1001/jama.297.4.407

Lerner, J. (2003). *Beyond Civil Society. Public Engagement Alternatives for Canadian Trade Policy.* Toronto: Canadian Institute for Environmental Law and Policy.

Mutemba, S. (1996). *Public participation in Environmental Assessment for Banks Supported Projects in sub-Saharan Africa, in Environmental Assessment in Africa: A World Bank commitment, Environmental Department*. World Bank Washington DC.

Mwalyosi, R.,Hughes, R. (1998). *The Performance of EIA in Tanzania: an Assessment.* London: International Institute for Environment and Development,

Nwafor, C.J. (2006). *Environmental impact assessment for sustainable development. The Nigerian perspective.* Enugu: Environment and Development Policy Centre for Africa.

Nwafor, C.J. (2009). Environmental Impact Assessment Practice in Nigeria: Achievements and challengegs. In: *Proceedings of the 16th Annual National Conference Environment and Behaviour Association of Nigeria.* Nigeria: Abeokuta.

ODA (1996). *Manual of Environmental Appraisal. Overseas Development Administration*. Revised July 1996, p.131.

Stephenson, D. et al. (1994). *Public Participation in EIA: A Review of Experience in Europe and the UK*. DRAFT. Centre for Environmental Management and Planning. Edinburgh: Aberdeen University Research and Industrial Services Ltd.

Umeh, L.C., Uchegbu, N. (1997). *Principles and Procedures of Environmental Impact assessment (EIA).* Lagos: Computer edge publisher.

United Nation (2006). Guidance on Public Participation in Environmental Impact Assessment in a Transboundary Context. United nations publications.

Wasserman, C. (2012). *Strengthening Public Participation in Environmental Management in Indonesia Training Workshop*. Jakarta, Indonesia

World Bank (1993). *Public Involvement in Environmental Assessment: Requirements, Opportunities and Issues*. Environmental Assessment Sourcebook Update No. 5. Washington D.C.

DOI: 10.23968/2500-0055-2018-3-1-13-20

STRUCTURAL PROPERTIES AND OPERATIONAL PHILOSOPHY OF THE VEHICLE WITH THE QUANTUM ENGINE

Jurij Kotikov

Saint Petersburg State University of Architecture and Civil Engineering
Vtoraja Krasnoarmejskaja ul. 4, St. Petersburg, Russia

cotikov@mail.com

Abstract

Successes of physics of last decades have designated prospect of the new technological way; use of antigravitational principles of moving of objects and a propulsive drive will be its basis. At conceptual level possibilities of use of the quantum engine (QuEn) on motor transport are considered.

QuEn does not demand the external energy carrier on the basic operating modes of the car. QuEn, creating impulse of the traction force transferred directly on the frame of a vehicle, does a power drive of wheels unnecessary - all the wheels work in a conducted mode.

Formation of vertical making traction force can provide partial suspension or pressing down car that is important for flotation ability. A number of other properties is mentioned also. Attempt of forecasting of configuration of the QuEn-car is carried out.

Keywords

Automobile, the quantum engine, structural properties, operational philosophy.

Introduction

By the beginning of the 21st century, physics advances have brought the humanity to the era of quantum energetics using global vacuum energy. Breakthrough theories of B. Parker (Parker, 1991), P. Davies (Davies, 1985), H. Puthoff (Puthoff, 2010), A. Veinik (Veinik, 1991), A. Nikitin (Nikitin, 2016), V. Leonov (Leonov, 1996, 1997, 2002, 2009, 2010, 2013, 2016, 2017a, 2017b, 2017c, 2017d) and other physicists were somehow aimed at searching, discovering and formalizing of the unified field, the existence of which was predicted by Einstein (Parker, 1991).

Unveiling the unified field comprises the key to mastering the ability to draw energy from the world's vacuum.

Realization of this phenomenon will result in a new technological paradigm involving the transport sector as well. And then, quantum engines will likely replace internal combustion and jet engines. Let us briefly analyze what structural and operational properties of vehicles with the quantum engine will be affected by those changes.

At first, it is necessary to review physical foundations of quantum energetics.

Physics advances at the turn of the 20th and 21st centuries

Modern energetics is based on the fundamental knowledge gained in the 19th and 20th centuries: the Faraday's law of induction, Maxwell's equations, discoveries of the kinetic-molecular theory of heat, quantum of radiation, structure of the atomic nucleus, radioactivity, etc. Those discoveries made it possible to use the energy of chemical fuel and energy of the atomic nucleus to produce mechanical and thermal energy, perform their conversion into electrical energy and deliver such energy to the consumer (Kotikov, 2006). However, the latest achievements in physics ((Leonov, 2017a) and others) allow coming ever closer to the establishment of a whole new level of energetics — quantum energetics — which will form the basis for a new technological paradigm in the world economy.

Applied physics of the 20th century considered the space-time as absolute emptiness with no structure (based on verified and utilized practical effects and achievements in theoretical physics of the past decades) (Leonov, 2017b).

Einstein introduced the concept of the unified field (replacing the mechanistic ether having no experimental evidences with the concept of four-dimensional space-time as the unified field (Shkrudnev, 2017)), but he did not consider space as absolute emptiness. He believed that "the existence of an empty space must be excluded" (Parker, 1991).

Einstein dreamed of a unified theory which would cover all physical phenomena — the unified field theory. But he never succeeded in creation of such theory covering all physical phenomena and overcoming the gap between the general theory of relativity and the quantum theory, giving a unified interpretation of all fields and their interaction with elementary particles (although he devoted the last 30 years of his life to this). Other major scientists — Heisenberg, Eddington, Pauli (Pauli, 1975) — also dedicated decades of their lives to achieving this goal which was unattainable for them. This can be explained by the fact that at that time there were not enough developments in theoretical and experimental physics to formalize their insights.

The Einstein's idea of the space-time field structure as a unified field (Parker, 1991), the Davies's idea of "superforce" uniting everything in the universe (Davies, 1985) and the Puthoff's idea of great energy density of the physical vacuum (Puthoff, 2010) were taken together and implemented by Russian scientist Leonov V. S. in his theory of the elastic quantized medium (EQM) (Leonov, 1996, 1997) and the theory of Superunification after discovery of the space-time quantum (quanton) (Leonov, 2010a).

The EQM theory determines the structure of the vacuum space as densely filled with the zero element (ZE) of the Mendeleev's periodic table (Leonov, 2017c). Mendeleev predicted its existence, tried to find it and even included it into the original version of the periodic table. He named it newtonium (Mendeleev, 1905). Mendeleev put high hopes on this imperceptible element. "Neither gravity nor any of the problems of energy can be rightly understood without a real conception of the ether as a universal medium transmitting energy at a distance", he wrote (Mendeleev, 1905). However, since neither the author of the periodic table nor any of his contemporaries were able to determine, formalize or prove the existence of the zero element, this hypothetical element was removed from the periodic table adopted by the scientific community for practical use.

The zero element missing in the periodic table (according to Mendeleev, the remaining elements cannot be formed without it) was brought back to life by Leonov V. S. in 1996 (Leonov, 1996) (due to replacement of the ether concept with the EQM concept) who named it quanton (recently, Leonov also raised an issue of returning the zero element to the Mendeleev's periodic table (Leonov, 2017c)).

The theory of Superunification (Leonov, 2010a) considers the process of Einstein's space-time quantization. Quantization is an energy process related to space filling with quantons. Quanton is not an elementary particle. It has a complex structure which includes four whole quarks: two electric (+1e and -1e) and two magnetic (+1g and -1g) quarks forming a tetrahedron with two orthogonal force axes (dipoles) — electric and magnetic. In general, two dipoles form an electromagnetic quanton quadrupole. Four mentioned quarks, that make up a quanton, combine electricity and magnetism in the form of a unified electromagnetic substance, the carrier of which is four-dimensional quantized space-time (QST) (Figure 1 (Leonov, 2013)).

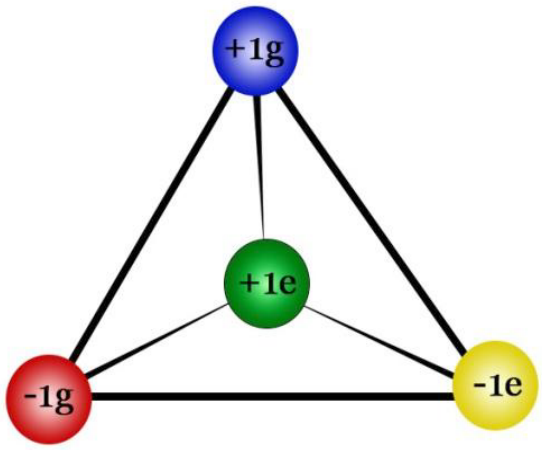

Figure 1. Quanton tetrahedron

The global vacuum (including all material insertions) is densely filled with mobile quantons representing a "boiling bouillon".

Quantons interact (attract and repulse) continuously due to their proximity, charge sign in adjacent quarks of neighboring quantons and orientation of dipole axes (see Figure 2 (Shkrudnev, 2017).

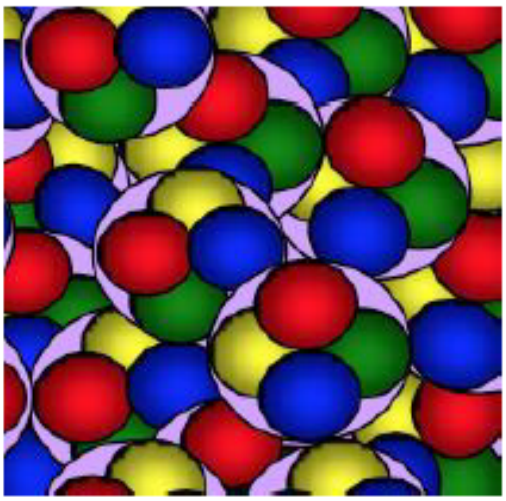

Figure 2. Quanton "broth" — quantized space-time

DOI: 10.23968/2500-0055-2018-3-1-13-20

The QST in the equilibrium state is an electromagnetic static field which is a carrier of super-strong electromagnetic interaction (SEI) — the fifth fundamental force (which Einstein and Davies were trying to find). SEI is that unified field combining gravity and electromagnetism, mentioned by Einstein in his general theory of relativity (GTR) (however, he failed to combine those). As a carrier of SEI, the QST possesses great energy density of approximately 10^{73} J/m^3 (Leonov, 2013).

The equilibrium state of a QST fragment implies that resultant vectors of axial forces of quark dipoles are zero in any direction (zero vectors). Introduction of a material object (containing a lot of free quarks) into the fragment perturbs the electromagnetic field, bending it relative to the initial equilibrium state (the resultant force zero vector acquires magnitude and direction). Control of free quarks' introduction allows affecting changes in the vector.

The discovery of the quanton in the form of a four-dimensional particle of a space-time quantum made it possible to give the GTR a quantum character. It also allowed V. S. Leonov to develop a quantum theory of gravity proceeding from the Einstein's concept of curved four-dimensional space-time as the basis of gravity.

It should be noted that the physical vacuum, penetrated by the elastic quantized medium, is subject to wave perturbations:

1) electromagnetic waves caused by the transverse electromagnetic polarization of quantons in space; 2) gravitational waves caused by the longitudinal deformation of the EQM; 3) torsional vibrations caused by the rotation of electromagnetic superstrings in the EQM (Leonov, 1997).

Leonov experimentally ascertained a ponderomotive (power conversion) interaction between electromagnetism and gravity. Actual anti-gravity effects were found. Experimental studies showed that external fields can interact with the EQM structure, resulting in stable anti-gravity effects (Leonov, 1997).

We can consider the outer space as an elastic super energy-dense medium having an electromagnetic structure with overall support and sufficient energy. All that is left for us to do is to learn how to interact with the environment and manage this interaction (Leonov, 1997).

As it is stated in the theory of Superunification, all known types of energy (chemical, nuclear, electromagnetic, gravitational, mechanical, etc.) imply extraction of SEI global energy and its further transformation allowing opening up a new direction in energetics — quantum energetics (Leonov, 2010a).

Quantum engine framework

The operation principle of quantum engines is based on the interaction of the field of a rotating electromagnetic quadrupole with the quantized medium (vacuum field). The quantum engine operation is based on the quantized space-time curvature (deformation) effect. As a result of this interaction, thrust appears, which affects movement in space (Leonov, 1997).

In the EQM theory, the Lorentz force (Repchenko, 2017) (which is directed towards the region of minimum magnetic field strength) is of great importance. Its character is associated with space deformation in a local region. This deformation can be created artificially as in a current circuit. The effect of the Lorentz force during rotation of an electromagnetic quadrupole is of particular interest as the quadrupole experiences axial thrust during rotation. The quadrupole is as though screwed into the medium, pushed away from it and, as a result, moves forward like an air propeller (Leonov, 1996). The quadrupole thrust value is determined by the charge e(g), rotation frequency and coefficient KR (which manifests at relativistic velocities).

Thus, if a quanton with its structure of the electromagnetic quadrupole is forced to rotate, then field thrust appears, which can cause it to move in space (together with the structural enclosure of the working chamber in a quantum engine) at a high speed.

Therefore, physics of the process is based on the interaction of fields (the rotating field of the electromagnetic quadrupole and the sign-alternating field of the quantized medium). In other words, quantum engines are engines, thrust of which is caused by the interaction of fields.

In a quadrupole cell, the quadrupole is held and rotates without energy emission beyond the structural enclosure. It is a structural property of quantum engines. Based on this property, in quantum engines, almost 100% of energy are converted into motion. In conventional chemical-fuel engines, such conversion cannot be obtained: their conversion efficiency is extremely low (Leonov, 1996).

According to Newton's third law, for every action there is an equal reaction and thrust is created due to repulsion from another mass or body. As for car wheels, they repulse from the road surface. In the jet engine, thrust is created due to the ejection of reactive mass, as if repulsing from this mass. Air and hydraulic propellers, screwing into the air or hydraulic medium, reject the mass of such medium, repulsing from it.

But is it possible to repulse from vacuum? The theory of Superunification states that it is possible if we consider the space vacuum as an elastic quantized medium (quantized space-time (QST) of primary nature) from which it is possible to repulse (Leonov, 2010a).

The theory of Superunification also states that weightless quantized space-time penetrates all weighable bodies. In this case, all weighable bodies represent an integral part of weightless quantized space-time. The body mass is formed as a result of the spherical deformation (bending according to Einstein) of weightless quantized space-time by elementary particles making up the body. In this case, the body mass represents an integral part of the elastic quantized medium, its energy cluster. The mass, as a gravitational charge, is a secondary formation in quantized space-time (Leonov, 2010a).

All known methods of producing thrust are based on the external action with the repulsion from the known media. In this case all known apparatuses for thrust generation shall be treated as closed quantum-mechanical systems. In accordance with the theory of Superunification, the quantum engine is an open quantum-mechanical system where thrust is created inside the body of the operating unit (activator) of the quantum engine.

To create thrust without the ejection of reactive mass it is necessary to switch over to the open quantum-mechanical systems, treating quantized space-time as an elastic quantized medium. Consequently, it is possible “to push away” from such an elastic quantized medium thus generating thrust. In this case, there are no contradictions with Newton’s third law, whose fundamentality was thoroughly checked and completely confirmed by the theory of Superunification (Leonov, 2010a, 2010b).

The very process of creating the thrust inside the operating unit of the quantum engine is connected with Einstein’s "bending" of quantized space-time. Based on the theory of Superunification, the Einstein's bending of space-time looks like a real deformation of the elastic quantized medium inside the operating unit of the quantum engine (Leonov, 2010a).

This deformation redistributes the quantum density of the medium inside the body of the operating unit of the quantum engine. This leads to the appearance of gradient thrust forces inside the operating unit. Thus, for the first time gravity and inertia are controlled. This once again confirms the fundamentality of the Einstein’s theory that gravity is based on bending of quantized space-time (Leonov, 2010b).

The deformation of QST in the local region inside the operating unit (activator) of the quantum engine corresponds to the energy which is spent by the body on its acceleration. In this case, we have the classical law of energy conservation. Deformation of vacuum takes place in the body of the operating unit of the quantum engine which actively interacts with the vacuum medium which penetrates the body. The internal thrust force appears inside the body of the operating unit. This is not external repulsion as in the jet engine, it is internal repulsion. If the classical theory forbids motion without the ejection of reactive mass, the theory of Superunification permits this motion (Leonov, 2010a).

Thus, quantum engines are engines, thrust of which is caused by the interaction of fields (Leonov, 1996).

It should be noted that, during motion with acceleration, particular regimes form inside QST when energy recovery is observed during deceleration, therefore, the consumed energy returns and can be used again. Such regimes are used in hybrid circuits of automobiles with electric transmission or in electric trains. In other words, inertia has a capacity for energy recovery.

Inertia regimes with energy recovery can be actively used in quantum engines. The capacity of quantum engines for energy recovery during thrust generation provides economical power cycles in quantum engines. It is necessary to compensate energy losses due to friction in engine mechanisms and ohmic losses in electrical wires and windings of activators (Leonov, 2010b).

The efficiency of the quantum engine during thrust generation can exceed that of conventional engines 20 or more times. However, to activate SEI energy in the quantum engine, additional power is required which would compensate heat losses in wires and bearings. However, those losses are within 5% (Leonov, 2010b).

Quantum engines: prototypes of engineering designs and development models of machines with quantum engines

Prototypes of quantum (field, vacuum) engines and energy sources were described in works of N. Tesla, S. Floyd, T. Brown, V. Shchabetnik, V. Leonov, V. Prokopyev, B. Ignatov, Yu. Ivanov, A. Miteshov and other inventors (Miteshov, 2015).

The Leonov's quantum engine is very promising as it has at least two laboratory models (Leonov, 2009, 2010b, Petrov, 2015). The concept, method and design of the quantum engine are protected by patent No. 2185526 (Russian Federation, priority date: 21.05.2001) "A method of thrust generation in vacuum and a field engine for spaceships (options)" (Leonov, 2002).

The technical result of the quantum engine (Leonov, 2002) is achieved by the following: during thrust generation in vacuum, the operating unit is exposed to a system of rotating crossing heterogeneous electric and magnetic fields, and, simultaneously, electrical and magnetic properties are set for such operating unit. In these circumstances, the quantum density of the vacuum field environment is redistributed inside the operating unit in a direction opposite to the thrust vector caused by the deformation of the vacuum field.

Meanwhile, the operating unit rotates. The thrust vector is divided into two vectors (normal and tangential). The normal vector allows producing thrust. The tangential vector allows producing torque providing power to supply the system of crossing heterogeneous electric and magnetic fields and system of their rotation.

Despite the fact that this patent has rather simple description for the design of operating units (activators) and operation principle of the quantum engine, it took the author years to create an operative structure. With a unit mass of 50 kg (including the chassis), he managed to achieve a thrust of 0.1 N, and in 2009 this value increased to 500 N (Leonov, 2009).

In 2014, a prototype quantum engine (1 kW) produced a thrust of 5,000 N in pulse (for comparison, a modern 1 kW jet engine produces a thrust of only 1 N) (Petrov, 2015).

According to Leonov V. S., there are no restrictions regarding thrust of quantum engines. He developed a method for calculating the design parameters of the quantum engine for any thrust, including 1,000 N, 10,000 N and more (Leonov, 2010a).

DOI: 10.23968/2500-0055-2018-3-1-13-20

Conceptual schemes and advantages of cars with quantum engines, pointed out by V. S. Leonov

The main direction of laboratory researches on quantum energy is related to the development of quantum engine concepts for field space exploration. It also noted that air transport with field engines will be scarcely different from space transport.

Meanwhile, above-ground motor transport can undergo serious transformation.

Diagrams of quantum engine installation in cars are presented in Figure 3 (Leonov, 1997). Propulsive engine 2 is installed in the rear of the car (a). Motion is caused by propulsive field thrust *R*. It is reasonable to install engines generating horizontal and vertical thrust in high-speed cars (b).

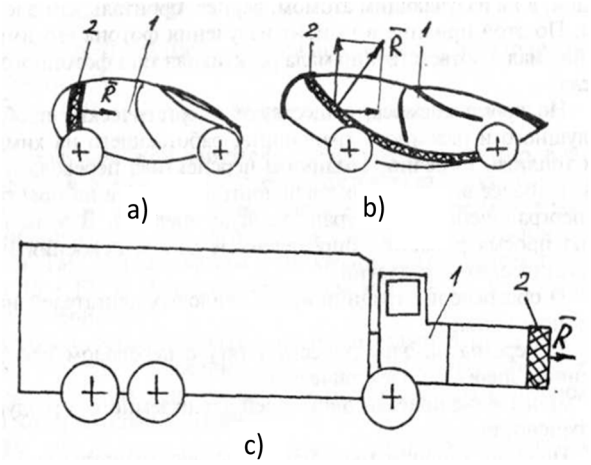

Figure 3. Diagrams of quantum engine installation in cars (Leonov, 1997): 1 – frame of a car; 2 - quantum engine

In this case, the load on wheels decreases. It is possible to install the engine at the front of the car (c), ensuring motion caused by thrust *R*.

A distinctive feature of cars with quantum engines is transmission removal. It allows for the installation of free suspension bracket of wheels. The car design includes the following components: a body, a quantum engine, and controlled wheels.

Despite the simple car design, implementation of quantum engines will require new cutting-edge technologies. Production of quantum engines can be expensive, therefore, such cars will be more expensive than those used nowadays (Leonov, 1997).

In Figure 4, a scheme of an off-road on an anti-gravity cushion, capable to overcome water obstacles, is presented (Leonov, 2010a). This off-roader will be able to move as a flying car at a certain height from the water surface.

Altitude control (when flying over obstacles) will be provided by an automation system controlled by radar scanner 3. The radar scanner will ensure safe movement of the car, preventing collisions. The radar-scanner with microprocessor control is capable to control car movement in the autopilot mode.

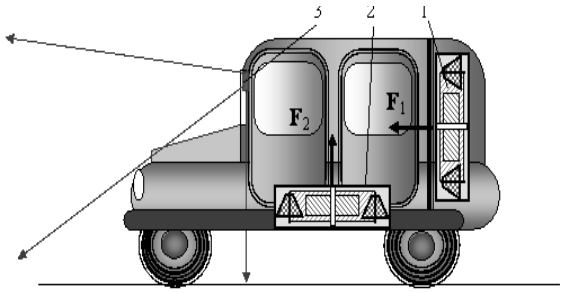

Figure 4. An off-road vehicle on an anti-gravity cushion with two quantum engines 1 and 2 — with horizontal F_1 and vertical F_2 thrust and radar scanner 3

The main advantages of the quantum engine compared to conventional engines, pointed out by Leonov, are as follows (Leonov, 2010a):

1) no chemical fuel is required for quantum engine operation;
2) unlimited movement distance without refueling;
3) significant reduction in material costs for traffic infrastructure (filling stations, power transmission lines for city transport, etc.);
4) high environmental friendliness and safety;
5) The quantum engine allows starting the car with fixed thrust, making maximum use of its power, avoiding losses inherent in ICE under unstable conditions (ICE lose 80% power due to low efficiency at low engine speed during starting, 50% power — during clutching; as a result, ICE use only about 10% power at the start of the car).

Design features of cars with quantum engines and differences between such cars and cars used nowadays

Let us try to predict possible design and operating features of the car with a quantum engine in detail (compared to modern cars with an ICE or electric engine), from the point of view of an expert-automobilist.

Obviously, we cannot perform an adequate analysis of all car properties (due to the lack of any data as designs of cars with quantum engines do not exist yet).

However, according to the author's opinion, their review can be useful for developers of future concept designs:

1. The loading pattern will change: the suspension can become less elastic, and the body — more durable. Earlier, the total propulsive force was used to propel both sprung and unsprung weights. In quantum engines, the propulsive/pulling force is used to propel the sprung weight with a rear-/front-positioned quantum engine, but the propulsive force is always applied only to the sprung weight.
2. If the body of the modern car is designed in such a way that the front and rear parts of the load-bearing

structure are easily deformed during collision, then, in cars with quantum engines, the frame and body shall be rigid and reliable (at least in components transmitting traction).

3. The point of traction application is located above wheel axles (particularly, above point of tire contact) which can change the movement mechanics.

4. Lack of longitudinal and transverse reaction overturning moments in cars with quantum engines.

5. In case of a front-mounted quantum engine (see Figure 3c), this propulsion unit becomes a rigid anchoring point for the "towed" car, which would result in increased angular vibrations of the car (with two degrees of freedom) around this point. It will adversely affect the car stability, dimensions of the dynamic movement corridor, vibration load of the structure, cargo safety and comfort of passengers.

6. Cars with quantum engines do not require a main power drive: gearbox, drive shafts, a main reduction gear, and pivot joints for front-wheel drive cars.

7. No inter-wheel and inter-axle differentials, or free-running differentials (for special machines) are required.

8. Absence of drive shafts, final drive housings and differentials makes it possible to arrange a clad floor, which improves the cross-country ability, reducing whirling and air resistance.

9. The possibility of implementing significant accelerations (more than 1g), both negative and positive (the maximum will be restricted by biomechanical limits of passengers and drivers).

10. Automatic energy recovery during cyclic movement.

11. Traction orientation along the longitudinal axle (especially in case of a front-mounted quantum engine, see Figure 3c) will lead to insufficient cornering ability due to large front slip angles (it is a disadvantage compared to modern front-wheel drive cars). This will require a turned vector of traction generated by the engine.

12. A controlled vertical (anti-gravity) component of traction will allow "suspending" the vehicle, improving its off-road mobility.

13. It is possible to use two quantum engines in all-terrain vehicles: for horizontal and vertical traction (see Figure 4).

14. According to the author's opinion, it is possible to install one quantum engine with the transverse axis of turning (or with hinge mounting to the body) to regulate the magnitude and direction of the traction vector. It will improve controllability and off-road performance.

15. This advantage of hinge mounting allows using steering wheel handle, which will improve ergonomics, controllability, cornering ability and off-road performance.

16. Essentially, it means transition to the "auto-avia-craft".

17. Better cross-country ability in comparison with modern cars.

18. No wheel slippage (irrespective of roads and longitudinal forces).

19. A vertical vector can put pressure on wheels on wet roads and in other conditions of insufficient adhesion.

20. Cars with quantum engines can climb steep hills (even without high-speed dynamics).

21. The danger of rollover is eliminated/reduced when the transverse force vector is used by an automatic control system and/or the connection with the steering wheel handle. Cars with quantum engines will be able to move over steep hillsides.

22. Wheels turn around the vertical axis more easily and simultaneously on all axles. It facilitates maneuvering.

23. Cars with quantum engines can still require an independent drive for wheels to facilitate maneuvering. In this case, it will be easier to implement the connection with the parking radar compared to such connection in modern cars.

24. Automatic cruise control will make driving easier (no transmission is required (neither mechanical nor automatic); no servo-motor drive for throttle or engine injector is required; no partial braking is required).

25. The emergency braking system will be more effective: a vertical force vector will put pressure on wheels to maintain roadholding during corner braking, with optimization of weight distribution of vector components by axles and wheels.

26. Complex downhill assist control systems (with use of the main brake system, engine brake and ABS) will be unnecessary. During motion of the car with a quantum engine, the traction vector shall be reversed and its value shall be adjusted (wheels will not slip). The downhill assist control system (if any) will be simpler.

27. Noise level: wheels used only in the driven mode will make less noise, and the engine, hopefully, will too.

28. No vibration (therefore, noise) from elements of the power drive.

29. It is still unclear how the quantum engine will be cooled, what thermal impact on a driver and passengers will be. It is also unclear if thermal protection is required.

30. Atmospheric conditions will not affect the operation of the quantum engine.

31. Less chemical emissions. The level and biological effect of high-frequency oscillations in quantum engines are still unclear.

32. Less tire wear.

33. No need for regular refueling.

34. The entire system of car maintenance will change.

35. Changes in roads and traffic regulations for cars with quantum engines will be observed as well.

Conclusion

Despite the lack of global experience in development of cars with quantum engines and their mass-production models, it was possible to review aspects of their development and operation.

The judgmental forecast allowed distinguishing a number of certain advantages of cars with quantum engines (compared to modern cars): simplified design; higher level of acceleration and braking

DOI: 10.23968/2500-0055-2018-3-1-13-20

dynamics, stability, controllability, chemical environmental compatibility, noise compatibility; no need for regular refueling, automatic energy recovery, less tire wear, etc.

It is still unclear what noise and high-frequency characteristics will quantum engines have, what influence of local deformation of the gravity field on the human body and other innovations will be. Properties with significant changes (possibly, in the undesirable direction) were also noted; they will require new calculation methods, research methods and solutions, e.g. regarding loading patterns.

The author's opinion is that the oscillatory systems shall be reviewed as well.

Obviously, mass production cars with quantum engines will lead to significant changes in the entire infrastructure and transportation technology.

References

Davies, P. (1985). *Superforce.* New York: Touchstone.

Kotikov, Ju., Lozhkin, V.N. (2006). *Transportnaia energetika [Transport energetics].* Moscow: Publishing Center "Academia", p.272. (in Russian)

Leonov, V.S. (1996). *Teoriia uprugoi kvantovannoi sredy [Theory of elastic quantized medium].* Minsk: Bisprint, p.156. (in Russian)

Leonov, V.S. (1997). *Teoriia uprugoi kvantovannoi sredy. Chast 2 . Novye istochniki energii [Theory of elastic quantized medium. Part 2. New energy sources].* Minsk: Polibig, p.122. (in Russian)

Leonov, V.S. (2002). Patent No. 2185526 (Russian Federation). *Sposob sozdaniia tiagi v vakuume i polevoi dvigatel dlia kosmicheskogo korablia (varianty)* [*A method of thrust generation in vacuum and a field engine for spaceship (options)].* Bulletin No. 20 dd. 20.07.2002 (priority date: 21.05.2001). (in Russian)

Leonov, V.S. (2009). *Rezultaty ispytanii 2009 goda kvantovogo dvigatelia dlia sozdaniia tiagi bez vybrosa re-aktivnoi massy [Quantum engine test results regarding thrust generation without ejection of reactive mass (2009)].* Available at: http://www.rnto.club/up/files/321/rezultati_ispitaniy_2009.pdf (accessed on: 28.01.2018) (in Russian)

Leonov, V.S. (2010). *Quantum Energetics. Volume 1. Theory of Superunification.* Cambridge International Science Publishing, p.745.

Leonov, V.S. (2010b). *Kosmos: rezultaty ispytanii kvantovogo dvigatelia dlia sozdaniia tiagi bez vybrosa [Space: quantum engine test results regarding thrust generation without ejection].* Available at: http://www.astronomy.ru/forum/index.php/topic,77730.0.html (accessed on: 28.01.2018) (in Russian)

Leonov, V.S. (2013). *Einstein vs Higgs: or what is the mass?* Available at: http://www.trinitas.ru/eng/doc/0016/001e/3139-ln.pdf (accessed on: 28.01.2018)

Leonov, V.S. (2016). *Kosmicheskii minikorabl s kvantovym dvigatelem doletit do Alfy Tcentavra za 8 let [Mini spaceship with a quantum engine will reach Alpha Centauri in 8 years].* Available at: http://leonovpublitzistika.blogspot.ru/2016/04/8.html (accessed on: 28.01.2018) (in Russian)

Leonov, V.S. (2017a). *O nauchno-tekhnicheskoi revoliutcii [On the scientific and technological revolution].* Available at: http://www.quanton.ru/o-nauchno-tehnicheskoj-revoljucii/ (accessed on: 28.01.2018) (in Russian)

Leonov, V.S. (2017b). *Novye energeticheskie kontceptcii [New energy concepts].* Available at: http://www.quanton.ru/novye-jenergeticheskie-koncepcii/ (accessed on: 28.01.2018) (in Russian)

Leonov, V.S. (2017c). *Otkrytie nulevogo elementa tablitcy [Discovery of the zero element in the Mendeleev's periodic table].* Available at: http://zg5.cosmotest.ru/leonov7.php (accessed on: 28.01.2018) (in Russian)

Leonov V.S. (2017d) *Kvantovye dvigateli-generatory [Quantum engine-generators].* Available at: http://www.quanton.ru/kvantovye-dvigateli-generatory/ (accessed on: 28.01.2018) (in Russian)

Mendeleev, D.I. (1905). *Popytka khimicheskogo ponimaniia mirovogo efira [An attempt towards a chemical conception of the ether].* Saint Petersburg: M. P. Frolova's tipolithography. (in Russian)

Miteshov, A.A. (2015). *Vakuumnyi dvigatel - budushchee kosmonavtiki [Vacuum engine is the future of space exploration].* Available at: http://www.avmodels.ru/news/interesting/index_full.html?id=4333 (accessed on: 28.01.2018) (in Russian)

Nikitin, A.P. (2014). K energodinamike dvizhushchegosia kosmosa [To the energy dynamics of moving space]. *Zhurnal russkoi fizicheskoi mysli [Journal of Russian Physical Thought]*, 1-12, pp. 103–118. (in Russian)

Parker, B. (1991). *Mechta Einshteina. V poiskakh edinoi teorii stroeniia Vselennoi* [*Einstein's dream. The search for a unified theory of the Universe] (translated from English by V. I. and O. I. Matsarskikh).* Moscow: Nauka, p.223. (in Russian)

Pauli, W. (1975). *Fizicheskie ocherki [Physical essays].* Moscow: Nauka. (in Russian)

Petrov, A. (2015). Rossiia uspeshno ispytala antigravitatcionnyi dvigatel Leonova [Russia successfully tested the Leonov anti-gravity engine]. http://www.km.ru/science-tech/2015/01/16/nauka-i-tekhnologii/753573-rossiya-uspeshno-ispytala-antigravitatsionnyi-dvi (accessed on: 28.01.2018) (in Russian)

Puthoff, H. (2010). Advanced Space Propulsion Based on Vacuum (Spacetime Metric) Engineering. *JBIS*, 63, pp. 82–89.

Repchenko, O. (2017). *Sila Lorentca v Polevoi fizike [Lorentz force in field physics].* Available at: http://www.fieldphysics.ru/lorentz_force/ (accessed on: 28.01.2018) (in Russian)

Shkrudnev, F.D. (2017). *Vselennaia: kipiashchii "bulon" iz kvantonov [The Universe: a boiling "bouillon" of quantons].* Available at: https://shkrudnev.com/index.php/home/drugie-avtory/v-s-leonov/item/1866-vselennaya-kipyashchij-bulon-iz-kvantonov-bulon-iz-kvantonov (accessed on: 28.01.2018) (in Russian)

Veinik A.I. (1991). *Termodinamika realnykh protcessov [Thermodynamics of real processes].* Minsk: Nauka i Tekhnika, p.576. (in Russian)

DOI: 10.23968/2500-0055-2018-3-1-21-28

COMPARATIVE ANALYSIS OF PAVEMENT RECONSTRUCTION METHODS

Alexander Kuleshov

"Trasstroy" LLC
187556, Leningrad region, Tikhvin, 3 microdistrict, 5, Russia

89216306314@yandex.ru

Abstract

The article deals with pavement reconstruction methods. Hot and cold recycling technologies are compared. Such technologies ensure significant savings compared to complete reconstruction and placement of additional layers on top of the existing pavement.

They also allow restoring road pavements according to high quality standards, within the shortest time possible and with minimum impact on the pavement. Examples of implemented pavement reconstruction projects using recycling are given.

Keywords

Pavement reconstruction, recycling, recycler, Remix.

Introduction

One of the most pressing issues both in Russia and abroad is deterioration of road pavements. The existing network of motor roads in the Russian Federation has poor transport and operational conditions. At the present time, 80% of roads in the Russian Federation need urgent repair.

Considering the fact that only 20% of road maintenance requirements regarding repaving are funded, it is necessary to determine the best option of road pavement repair.

Currently, the following methods are the most common in rehabilitation of flexible pavements:

• hot and cold recycling technologies;

• a conventional technology which involves removal of the existing pavement and construction of a new one at the same place or placement of additional layers on top of the existing pavement;

• road surfacing using mastic asphalt concrete.

According to economic evaluations, low efficiency of conventional options for rehabilitation of flexible pavements was revealed (Wirtgen, 2012).

Application of road surfacing technologies using mastic asphalt concrete is a rather expensive road repair option. As a consequence, it is very rarely used in road repair or reconstruction in Russia.

An option for rehabilitation of flexible pavements using cold recycling has the following advantages over complete reconstruction and placement of additional layers on top of the existing pavement:

• cost efficiency;

• high quality of rehabilitated pavements;

• short construction duration;

• minimum pavement deformation.

For those reasons, cold recycling is widely used in various countries (Wirtgen, 2012; Shipitsyn, 2006).

Besides cold recycling, hot recycling is used, when the existing asphalt concrete is heated using infrared rays and then hot-milled. After that it is loosened, re-spread and compacted.

However, hot recycling has several significant disadvantages:

• asphalt concrete heating using infrared rays causes considerable damage to the environment;

• a large amount of energy is spent during asphalt concrete heating, which makes this technology economically unprofitable;

• low durability of rehabilitated pavements.

Given the disadvantages stated above, in the late 1980s, many Western European countries almost abandoned rehabilitating flexible pavements using hot recycling, and cold recycling came to the fore.

Recycling technologies

Currently, both in the Russian Federation and abroad, cold recycling is widely used during road pavement repair and reconstruction. This technology allows using old pavement material most efficiently and minimizing damage to the environment. However, cold recycling poses the following problem: is is almost impossible to determine the thickness of the reclaimed layer without obtaining the stress-strain state. Problem solving according to the current standards does not allow taking into account the spatial nature of load applied by modern road trains, physical and geometric nonlinearity, and behavior of layer materials.

Repair requires significant financial resources which usually are not enough. An issue of innovation implementation to reduce repair and reconstruction costs with no compromise in quality becomes more pressing.

The existing approach applied in designing and conducting of road repair and roadway replacement works does not always allow using funds allocated for such purposes efficiently. It is assumed at this stage that road replacement shall include not only replacement of the wearing course but also replacement of the base course since not so much pavement condition as its bearing capacity can serve as a justification for road replacement.

As a result, in some cases design companies understate the actual results of pavement strength tests to justify the need for road replacement at a particular road section. While reconstruction of the base course at such sections is not necessary during road replacement, it is performed anyway.

At the same time, if a road section has sufficient bearing capacity and road replacement is required due to poor pavement condition, it is possible to use repair options which are twice more efficient than replacement of the existing base course.

Cold recycling is a modern progressive technology of pavement rehabilitation, involving milling of worn-out pavement, mixing of the milled pavement with binders and placement of a new pavement at the same place, followed by its compaction and arrangement of a finish layer. It is impossible to use cold recycling without a recycler – a special machine with a milling and mixing drum as the main working body (Figure 1). Rotating against the direction of recycler's travel, the milling drum ensures pavement destruction, milling, and mixing with water and bitumen emulsion.

Then grading of the recycled layer using a grader and subsequent compaction with a vibrating roller are carried out. The process is finished with arrangement of a finish layer.

Three options of cold recycling are distinguished:

- in-place recycling;
- in-plant recycling;
- combined option.

In-place recycling provides for performance of all process operations directly at the site of repair and rehabilitation works (Filatov, 2009; Wirtgen, 2012,; Shipitsyn, 2006).

In-plant recycling provides for use of stationary and semi-mobile mixers. An advantage of this option is in the possibility to exert quality control over materials composing the asphalt-concrete mix.

However, in-plant recycling has a significant disadvantage – transportation costs making the technology economically unprofitable. That is why many countries have almost abandoned in-plant recycling. Meanwhile, in-place recycling and the combined option have come to the fore.

Cold recycling option selection depends on the road location, topological and hydrogeological conditions, and availability of required materials (Wirtgen, 2012).

Cold recycling is carried out using organic, inorganic and combined binders. Binder selection, as cold recycling option selection, is a very complex and important task facing engineers.Bitumen emulsion and foamed bitumen are used as organic binders. Usually,

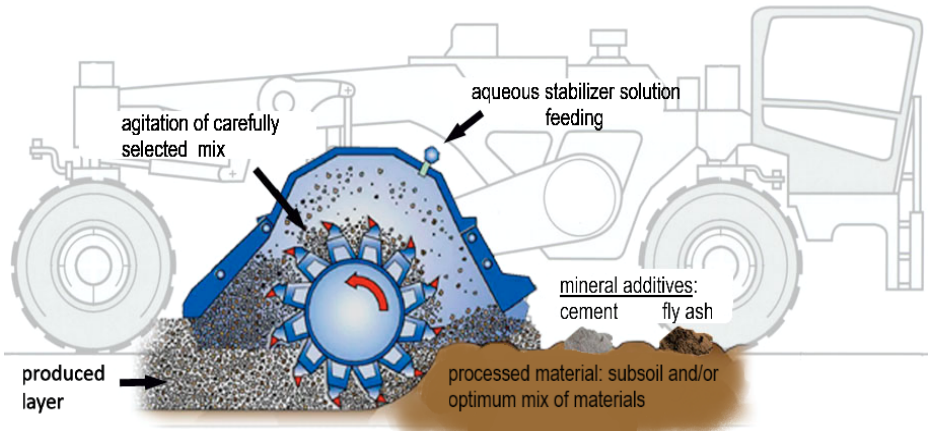

Figure 1. Recycling scheme

DOI: 10.23968/2500-0055-2018-3-1-21-28

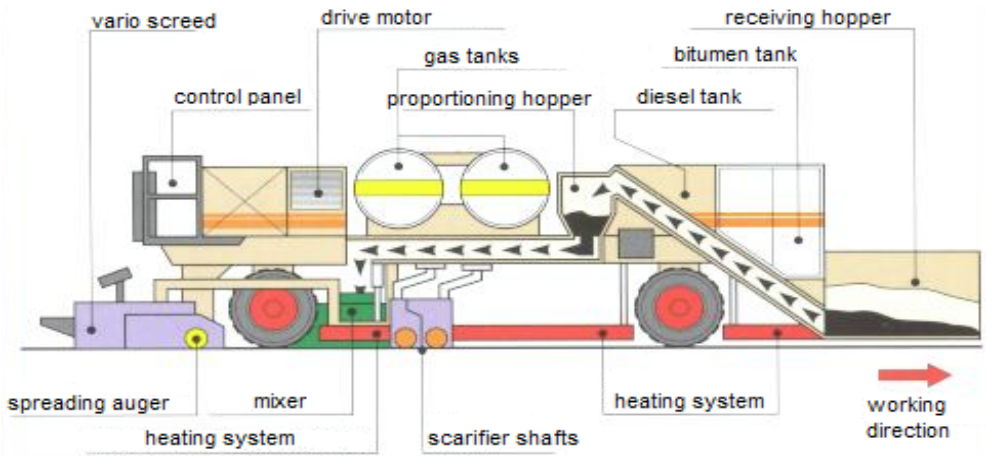

Figure 2. Asphalt-concrete pavement restoration using the Remix technology

bitumen emulsion is 60% bitumen and 40% water. However, the bitumen concentration can vary from 30 to 70%.

The use of foamed bitumen is accompanied by foaming with addition of water (approximately 2% of the total mass) at a binder temperature of 160...180°C. In this case, water expands 1,500 times as compared to its initial state.

As for inorganic binders, cement or lime can be used. Those binders are added with the sole purpose to increase the pavement compressive strength.

Currently, a combined binder (bitumen emulsion + water-cement suspension) is widely used both in Russia and abroad (AASHTO, 2004). Pavements made of milled asphalt concrete reinforced with a complex binder have higher resistance to deformation. This is due to the fact that in this material both coagulation and crystallization bonds are formed.

Contemporary challenges of hot asphalt-concrete recycling

Introduction of recycling processes, i.e. re-use of used materials, is an effective solution to problems of natural resources saving and waste recycling. One of important recycling objects is the asphalt-concrete pavement material. According to the data of L. Santucci (Santucci, 2007), the annual volume of asphalt-concrete recycling in the USA exceeds the total recycling volume of other strategically important materials (aluminum, plastic, paper, and glass).

The material of removed asphalt-concrete pavements can be used as a filler in road reconstruction and replacement. Mechanical manipulation of asphalt concrete allows obtaining high-quality material meeting applicable standards, which consists of a mineral part and a bituminous binder, and serves as a secondary raw material containing bitumen for RAM (recycled asphalt-concrete mix) production.

In 2011, the amount of reclaimed asphalt pavement (hot asphalt-concrete recycling) in the USA was 66.3 mln tons. It conserved more than 3.3 mln tons of asphalt binder (Acott, 2013). For a long time, the recommended content of the secondary raw material containing bitumen in RAM was limited to 25% due to economic reasons; in some cases, it was limited to 15% (for example, upon implementation of large-scale projects). In most cases, RAM were not recommended for the arrangement of the wearing course in asphalt-concrete pavements (Kandhal, 1997).

Two types of hot recycling can be distinguished: hot in-plant recycling with preparation of asphalt concrete mixes and hot in-place recycling.

Hot in-plant recycling with preparation of asphalt concrete mixes includes the following stages: removal of old asphalt concrete using milling, delivery to the plant, storage of asphalt-concrete granulated material, production of recycled asphalt-concrete mixes, their placement and compaction (Acott, 2013).

Hot in-place recycling is based on loosening of the heated asphalt-concrete pavement and its re-use; all operations are performed using special machines directly in situ. Restoration of worn-out asphalt-concrete pavements using hot recycling is performed with Remix and Remix Plus methods.

The Remix method is used for restoration of worn-out asphalt-concrete pavements by means of their recycling and improvement of their structural as well as physical and mechanical properties. The technology involves softening of the asphalt-concrete pavement with heat, its loosening to a depth of 60 mm, mixing of the obtained mix with additives (virgin mix, rock materials, plasticizers, mineral and organic binders), re-spreading, fixing and pre-compacting of the homogeneous recycled mix, maintaining necessary leveling and design pavement slopes in one passe of a remixer (Figure 2).

The Remix method is divided into the following options:

- thermal homogenization;
- thermal mixing;
- thermal plasticization.

Thermal homogenization involves asphalt-concrete recycling by means of heating, loosening, mixing, re-

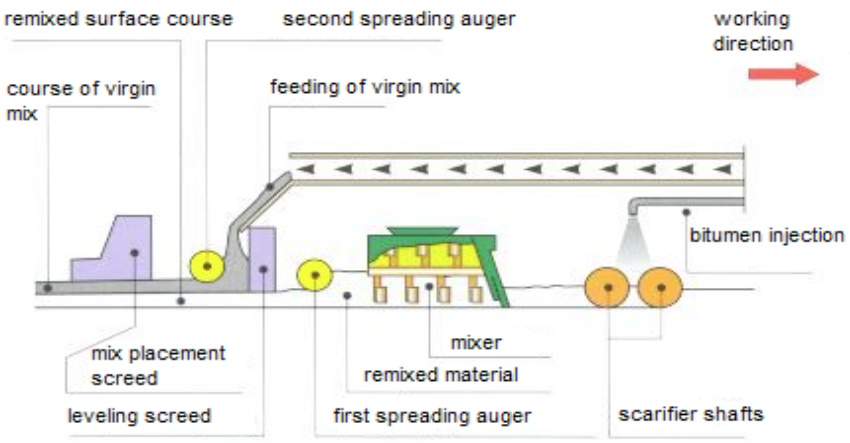

Figure 3. Asphalt-concrete pavement restoration using the Remix Plus technology

spreading and compacting of the old asphalt-concrete mix with a thickness of 3.0...6.0 cm.

This option is the most efficient, since it requires the minimum amount of virgin mix (about 20 kg/m^2) or does not require it at all.Thermal plasticization involves introduction of plasticizer additives into the pre-heated and loosened asphalt-concrete mix during its mixing. Liquid petroleum products are used as plasticizers. Virgin mix is added in minimum amounts – up to 20 kg/m^2.

Thermal mixing involves mixing of virgin mix with the old one after its heating and loosening, and fixing of the resulting mix in one layer. Thermal mixing has all advantages of thermal placement and ensures high quality of the reclaimed layer. The Remix Plus (thermal placement) method involves restoration of worn-out asphalt-concrete pavements by fixing two layers in one pass of a remixer (the lower layer made of the recycled mix and the upper layer as an additional layer).

The technology involves softening of the old asphalt-concrete pavement with heat to a depth of 60 mm, its loosening, mixing with additives (virgin mix, rock materials, plasticizers, mineral and organic binders), and placement maintaining necessary pavement leveling; an additional course of virgin mix with a thickness of 3.0...6.0 cm is laid (Figure 3).

Almost 90% of Russian public road need to be replaced. Therefore, the issue of applying modern efficient technologies in road construction is one of the most relevant. Considering the sharp increase in the cost of road construction materials in recent years (in the past decade, the cost of bitumen increased 10 times, the cost of gravel increased 5–8 times, and the cost of asphalt-concrete mix increased by 6–8 times), thermal homogenization appears to be the most promising option of hot recycling, as it is less expensive and allows re-using road construction materials. Taking into account the available experience in introduction of thermal homogenization in our country and analysis of foreign scientific and technical publications, the following advantages over other options of repair works, intended for rapid restoration of transport and operational conditions of roads, can be noted:

• complete operation cycle in one pass of special equipment, allowing reducing consumption of technical resources;

• reduction of repair work duration;

• pavement opening to traffic almost immediately after the completion of compaction, which is especially important in urban conditions for rapid traffic recovery;

• no need for disposal of the old asphalt-concrete pavement and use of new materials for its restoration;

• no need for pavement patching and crack sealing for further repair works;

• leveling of the repaired pavement;

• preservation of the existing pavement elevation points, which is especially important in streets of settlements and on bridge crossings;

• restoration of transverse and longitudinal slopes of pavements;

• rutting elimination.

One of the main problems in repair works using in-place hot recycling is heterogeneity of the old pavement which is re-used after mixing. Heterogeneity of the old pavement is due to the fact that during its operation it was repeatedly repaired using various technologies and materials.

Such heterogeneity can cause premature destruction of the repaired pavement, therefore, it is reasonable to arrange an additional layer at sections strongly affected by potholes after recycling. Issues of environmental safety during in-place hot recycling and the service life of pavements repaired using thermal homogenization need to be considered as well.

Considering that the cost of thermal homogenization depends significantly on gas consumption for pavement heating (in case of heating with infrared burners), which, in its turn, depends on the air temperature, wind speed and other weather conditions, it is reasonable to conduct research to reduce such energy consumption.

After consideration of engineering and cost aspects of in-place hot recycling and, in particular, thermal homogenization, it should be noted that the cost of such works is in the same price range as other options of

repair works, therefore, when selecting an option, a more technological method shall be preferred.

Thermal homogenization has many advantages over other technologies, which were confirmed at pilot sections, but, given the limited experience in its implementation in our country, there is no accurate data on the service life of repaired pavements.

Therefore, it is necessary to continue research in this direction. Both engineering and cost aspects of thermal homogenization demonstrate its promising application upon restoration of transport and operational conditions of roads, especially in case of limited funding and the need for rapid repair and traffic recovery.

The key direction in research of hot recycling is production of standard asphalt concretes with more than 25% secondary raw material containing bitumen, which requires solving a number of tasks associated with high content of secondary high-viscosity bitumen:

• ensuring heat transfer enhancement during RAM production;

• ensuring combination of the new bitumen and secondary bitumen, which can be achieved through increase in the RAM production duration;

• ensuring proper parameters of asphalt-concrete compaction.

Possibilities of heat transfer enhancement through heat carrier temperature increase are limited.

An alternative approach is reducing the technological viscosity of binders without RAM production temperature increase. The corresponding solution is combination of hot recycling technologies and technologies for production of hot asphalt-concrete mixes at low temperatures, based on the use of organic or chemical additives (Adoryani, 1988).

Chemical additives reduce the technological viscosity of binders without changing the linear dependence of the viscosity on the temperature. Those include surfactants and combinations of surfactants with emulsifiers (*Rediset WMX, Evotherm ET, Evotherm DAT, Evotherm 3G*) additives. Organic additives reduce the technological viscosity of bituminous binders and change the linear dependence of the viscosity on the temperature. Such additives mainly include synthetic waxes. As for hot recycling, the most studied additive is Sasobit additive (manufactured by Sasol Wax). It is a synthetic wax which differs from paraffin waxes in bitumen by higher molecular mass and melting point.

In 2006–2012, at the *National Center for Asphalt Technology (NCAT)*, a study on properties of asphalt concrete with the increased content of the secondary raw material containing bitumen (D'Angelo, 2008), including *Sasobit* modified binders, was conducted, and pilot sections with RAM placement (with a maximum grain size of the mineral part of 12.5 mm) in the top layer of asphalt-concrete pavements; the temperature of RAM discharge from the mixer varied from 143 to 160°C.

In the course of laboratory studies in accordance with ASTM D6648:01 (ASTM D6648:01, 2001), it was determined that asphalt concretes with 45% secondary raw material containing bitumen, including *Sasobit* modified binders, were characterized by expectedly high values of the dynamic modulus of elasticity *E* at high temperatures, and, according to the results of full-scale tests, ensured proper IRI (International Refining Indices) and high rutting (after application of 9,400,000 cycles of uniaxial load, the average values of rutting depth were from 1.1 mm to 2.0 mm).

When considering hot recycling implementation in the domestic road construction industry, it is necessary to solve the following tasks:

• determine the maximum allowable content of the secondary raw material containing bitumen, which would allow obtaining standard asphalt concrete of various grades without changing the requirements for bituminous binders and without use of plasticizers;

• determine the maximum allowable content of the secondary raw material containing bitumen, which would allow obtaining standard asphalt concrete of various grades without changing the requirements for bituminous binders, with application of plasticizers based on heavy petrochemical products.

When selecting the RAM composition, it should be noted that the characteristics of the recycled binder during RAM production differ from the characteristics of the binder, determined in the course of laboratory tests, since the combination of primary and secondary bitumen is incomplete during RAM production.

Comparative analysis of pavement reconstruction methods

Over time, roads deteriorate (irregularities and potholes appear) and become obsolete (the road bearing capacity becomes insufficient).

Pavement restoration requires a lot of effort: it is necessary to remove and transport the old pavement for re-use, and only then a new pavement can be laid. But it is even more difficult to increase the road bearing capacity. However, if the old pavement material is used directly on the roadbed, both tasks become significantly simpler. If the worn-out pavement is milled and crushed to the full depth, rock materials and binders are added (if necessary), everything is mixed and laid evenly, a new base is obtained, which is then compacted by rollers. This procedure requires special machines of high power and capacity, capable of milling to a depth of 300...600 mm, with a rotor diameter exceeding 1 m.

Such machines are already produced by leading foreign manufacturers of road construction equipment: Caterpillar (USA), Sakai, Niigata and Komatsu (Japan), Wirtgen and Bomag (Germany), and Bitelli (Italy).

Caterpillar, Bomag and Bitelli machines are made according to the same scheme. The Wirtgen company named its technology for road reconstruction using the old pavement material "cold recycling". Machines designed for such works are called "recyclers".

Cold recycling can be used both on rural and local roads, and on federal roads, on stabilized (wearing

course and base course) and non-stabilized (crushed stone) layers (https://os1.ru/article/6920-resayklery-mashiny-dlya-rekonstruktsii-dorog).

It is a modern, well-proven and unique method of pavement repair, ensuring base course restoration with the re-use of the old pavement material. This method allows shortening the time for reconstruction and repair, reducing costs significantly. Cold recycling operations are carried out without traffic stoppage (http://sdmachinery.ru/tehnologii/resajkling/).

In-place cold recycling has the following advantages:

1. No environmental pollution due to full utilization of the old pavement material; no need for dump sites; minimum volume of brought-in materials; minimum transportation; lowered energy consumption; reduced destructive impact of vehicles on the road network.

2. Quality of the reclaimed layer due to consistent mixing of materials obtained in situ with water and stabilizers. Liquids are introduced in exactly the right amount through the use of a microprocessor-based pump control system. The mixing process meets the highest requirements, since all components are forcibly mixed in a mixing chamber.

3. Pavement structural integrity. Cold recycling allows obtaining cohesive layers of large thickness, characterized by material homogeneity. Therefore, no liquid binders between thin pavement layers are required, which is sometimes necessary for pavements of standard structure.

4. Maintaining the soil integrity, as recycling causes less damage to low-quality soil than when standard road construction machines are used for pavement reconstruction. Usually, cold recycling is performed in one pass of a recycler with pneumatic tires which exert low pressure on the soil and cause only small deformation.

5. Reduction of construction work duration. Modern recycling machines are characterized by high efficiency of road construction, allowing for significant reduction of construction work duration in comparison with conventional methods of pavement restoration.

Reduction of construction work duration is beneficial for road users, because as a result, traffic is closed for a shorter period.

Those advantages make cold recycling the most attractive technology for pavement reconstruction by cost/efficiency ratio. Let us perform a comparative analysis of pavement reconstruction methods (Table 1).

It is evident from the analysis that cold recycling allows excluding several operations from the process. There is no need to arrange a bypass road; works related to pavement dismantling, as well as to transportation and disposal of the obtained materials are excluded.

Arrangement of sandy and crushed-stone base courses is not required, since the existing base course is not damaged during recycling.

The number of machines involved in construction works significantly decreases (http://sdmachinery.ru/tehnologii/resajkling/).

Table 1. Comparative analysis of pavement reconstruction methods

List of works required using conventional reconstruction methods:	List of works required using cold recycling:
• construction of a bypass (temporary) road; • pavement dismantling using bulldozers, excavators; • transportation of materials obtained during dismantling and their disposal; • longitudinal grading; • stabilization (compaction) of the base course by rollers and treatment with bituminous compositions; • arrangement of a sandy base course; • arrangement of a crushed-stone course in 3 layers (fractions) with compaction of each layer by rollers; • tack coating with bituminous compositions; • arrangement of an asphalt-concrete pavement (according to calculations); • arrangement of shoulders by soil filling with layer-by-layer compaction; • shoulders' surfacing with crushed stone and their treatment with bituminous compositions.	• dry loosening to the designed depth; • pavement grading using graders; • pavement surfacing with high-strength crushed stone (if base course reinforcement is necessary); • loosening to the designed depth with bitumen emulsion injection; • pavement re-grading using graders; • compaction; • arrangement of an asphalt-concrete pavement (according to calculations); • extension of shoulders (if necessary).

Implemented projects

1. Construction of the base course with in-plant cold recycling. (Figure 4).

Location:

- R-22 Kaspiy road, M-4 Don road — Tambov–Volgograd–Astrakhan, km 1254+000 – km 1261+000, km 1265+000 – km 1272+000;

- R-216 Astrakhan–Elista–Stavropol road, km 55+000 – km 69+000. Astrakhan Region.

Implementation scope: 236701 m².

2. Construction of the base course with cold recycling, using WP-2500 recycler, with binder addition (Figure 5).

Figure 4. Construction of the base course with in-plant cold recycling (Federal Road Agency (Rosavtodor), 2016)

Figure 6. Cold recycling using WR-2500 Wirtgen recycler machines (complex binder: bitumen emulsion, cement) (Federal Road Agency (Rosavtodor), 2016)

Figure 5. Construction of the base course with cold recycling (using WP-2500 recycler, with binder addition) (Federal Road Agency (Rosavtodor), 2016)

Figure 7. Cold recycling with addition of foamed bitumen, cement and granulated slag (Federal Road Agency (Rosavtodor), 2016)

Location:

- R-22 Kaspiy road: km 848+000 – km 856+000;
- R-132 Kaluga–Tula–Mikhaylov–Ryazan road: km 240+00 – km 252+000.

Implementation scope: 161075 m².

3. Cold recycling using WR-2500 Wirtgen recycler machines (complex binder: bitumen emulsion, cement) (Figure 6).

Location:

- Syktyvkar–Troitsko-Pechorsk road: Lesozavod–Kochpon–Chit–Davpon section, km 0+000 – km 4+665;
- Syktyvkar–Troitsko-Pechorsk road: Syktyvkar–Puzla–Krutaya section, km 193+000 – km 207+000.

Implementation scope: 101672.3 m².

4. Cold recycling with addition of foamed bitumen, cement and granulated slag (Figure 7).

Location:

- Ryazan–Pronsk–Skopin road: sections km 29+230 – km 33+500, km 44+700 – km 46+400, km 75+000 – km 78+700, Pronsky District, Ryazan Region.

Implementation scope: 69350 m².

Conclusions

Pavements quickly deteriorate and lose bearing capacity. One of the main issues of road construction in Russia is weak base courses which are not designed for traffic load increased in recent decades. The cold recycling technology can be referred to as a breakthrough in pavement as it allows restoring pavements without heating, re-using the removed asphalt.

But it is even more difficult to increase the road bearing capacity. Cold recycling allows obtaining a high-quality road with a service life of 10–15 years, reducing construction duration by 3–5 times and providing up to 50% of budget savings.

Meanwhile, hot recycling methods become the most efficient when ensuring the adequate service life of the road. In this case, the service life can be doubled. Besides, the cost of pavement repair during the service life is reduced by half compared to conventional methods. Moreover, all roadway defects (cracks, potholes, rutting, scaling, cracking) are eliminated during hot recycling, and the modulus of elasticity increases.

References

AASHTO (2004). AASHTO M323-04 *Standard Specification for Superpave Volumetric Mix Design*.

Acott, M. (2013). *Reclaiming acclaim. Asphalt industry still leads the way in green practice*. Roads & Bridges, pp. 4–5.

Adoryani, K. (1988). *Razrabotka metodov optimizatsii sostava i tekhnologii prigotovleniia obnovlennykh asfal'tobetonnykh smesei pri remonte pokrytii [Development of methods for optimization of the composition and technology for preparation of new asphalt-concrete mixes for pavement repair].* PhD thesis in Engineering. Moscow, p.15. (in Russian)

ASTM D6648:01 (2001). *Standard Test Method for Determining the Flexural Creep Stiffness of Asphalt Binder Usingthe Bending Beam Rheometer (BBR)*, p.4.

D'Angelo, J. (2008). *WarmMix Asphalt: European Practice*. Report No FHWA-PL-08-007, p.68.

Gosstroy of the USSR (1989). SNIP 3.06.03-85 *Avtomobil'nye dorogi. Stroitel'nye normy i pravila [Motor roads. Construction rules and regulations]*. Moscow: Central Institure of Standard Designing, p.76. (in Russian)

Federal Road Agency (Rosavtodor) (2016). *Catalog of efficient technologies, new materials and modern equipment for the road industry*. Moscow, p.409.

Filatov, F.S. (2009). *Vostanovlenie asfal'tobetonnykh pokrytii metodom kholodnogo resaiklinga [Recovery of asphalt-concrete pavements using cold recycling].* Omsk: Publishing House of the Siberian State Automobile and Highway Academy, p.72. (in Russian)

Kandhal, P., Mallick, R. (1997). *Pavement Recycling Guidelines for State and Local Governments*. FHWA publ. No FHWASA98-042.

Santucci, L. (2007). Recycling Asphalt Pavement – A Strategy Revisited. *Tech Topic*, 8, pp. 1–12.

Shipitsyn, V.V. (2006). *Obosnovanie tekhnologii remonta asfal'tobetonnykh pokrytii metodom kholodnogo resaiklinga s primeneniem medlennotverdeiushchikh mineral'nykh viazhushchikh i razzhizhennogo bituma [Substantiation of the technology for asphalt-concrete pavement repair using cold recycling with application of slow-setting mineral binders and liquefied bitumen]*. PhD thesis in Engineering. Omsk, p.170. (in Russian)

Wirtgen GmbH (2012). *Wirtgen cold recycling technology*. Windhagen: Wirtgen GmbH, p.365.

DOI: 10.23968/2500-0055-2018-3-1-29-37

RESULTS OF STUDYING ROAD CONSTRUCTION PARAMETERS' CONDITION

Elena Kurakina [1], Stanislav Evtyukov [2]

[1, 2] Saint Petersburg State University of Architecture and Civil Engineering
Vtoraja Krasnoarmejskaja ul. 4, St. Petersburg, Russia

[1] elvl_86@mail.ru

Abstract

A system for the accounting of road infrastructure facilities' parameters specified during design and construction of motor roads. A study of parameters' condition was performed. Analysis of road accident rate statistics and identification of parameters to assess the efficiency of the proposed road construction activities aimed at the reduction in the number of road accidents were carried out.

Actual data on condition parameters with the use of modern automated multi-functional diagnostic equipment were obtained. Actions aimed at the improvement of road infrastructure parameters through traffic safety enhancement, as well as actions aimed at the reconstruction of the motor road or project-supported construction of road segments were developed. Efficiency of the proposed actions was assessed.

Keywords

Motor road, construction, reconstruction, road surface, vehicle, parameters, road accidents.

Introduction

Obtaining of studies results is based on the use of the improved system for accounting of parameters during design and construction of motor roads. Non-compliance with construction regulations has adverse effects during operation. In particular, it can lead to premature destruction of the road surface, appearance of rutting, low adhesion characteristics of the road surface, certain condition of the roadway and shoulders (especially in winter), producing accident-prone situations.

Generally, such factors decrease traffic safety decrease and increase the number of road accidents. Troubleshooting reduces to expert study which represents a set of successive systematic theoretical and practical methods or actions aimed at identifying the causes and factors that led to a failure in the Driver–Vehicle–Road–Environment (DVRE) system.

A failure in the system means operating trouble of one of the key components, i.e. Vehicle, Driver, Road or their combinations, including the Environment component, which, in their turn, cease to perform their assigned functions partially or totally, leading to violations in safe operation of the entire system.

Analysis of operating troubles or failure prevention are possible through qualitative expert study. Scientific studies of some parameters of the subsystem "Vehicle–Road" condition, performed by scientists Nemchinov M. V., Vasiliev A. P., and Domke E. R., are aimed at braking performance and characteristics of wheel adhesion with the road surface during operation and reconstruction of the latter (Kurakina, Evtyukov, 2017; Domke, 2012; Evtyukov, Vasiliev, 2012; Kurakina, 2014b; Suvorov et al., 1990). Scientists Suvorov Yu. B., Kikot I. M. and others (Evtyukov, Vasiliev, 2012; Kurakina, Evtyukov, 2015) were engaged in diagnostic studies of elements of operated motor roads at segments where road conditions affected traffic safety.

Kiryukhin G. N. proved the relevance of road surface diagnostics and determination of traffic flow characteristics with the use of a wide range of devices and equipment for testing and diagnostics of motor roads (Kurakina, 2016, 2017, Kurakina, Evtyukov, 2014, 2015).

Expert study is supported by various procedures, algorithms, methods, strategies, techniques and equipment, depending on the purpose of the expert study, its complexity and the number of questions posed. Subjects of various researches are reviewed in works of such scientists as Borovskiy B. E., Ilarionov V. A., Evtyukov S. A., Zamarayev I. V., and Stolyarov V. V. (Ilarionov, 1989; Kurakina, 2014b; Kurakina, Evtyukov, 2015).

However, during construction, the system of accounting for the main parameters of the "Road" subsystem is

specified by regulatory documents of the construction industry.

Mutual comprehensive studies of parameters conditions shall be carried out at all stages of construction, operation and reconstruction in order to prevent emergency conditions (Kurakina, 2014a; Kurakina, Evtyukov, 2014; Kurakina, Evtyukov, 2015; Kurakina et al., 2017; ROSDORNII, 2015; Suvorov et al., 1990). Based on such study, actions aimed at the improvement of road infrastructure parameters through traffic safety enhancement, as well as actions aimed at the reconstruction of the motor road or project-supported construction of road segments are developed.

Subject, tasks and methods

The study subject is parameters of above-ground transport and road infrastructure facilities' condition, as well as the number of road accidents as a result of their adverse effect.

The study tasks include the following:

− analysis of road accident rate statistics and identification of parameters to assess the efficiency of the proposed road construction activities aimed at the reduction in the number of road accidents;

− obtaining actual data on condition parameters with the use of modern automated multi-functional diagnostic equipment;

− development of actions aimed at the improvement of road infrastructure parameters through traffic safety enhancement, as well as actions aimed at the reconstruction of the motor road or project-supported construction of road segments;

− assessment of the efficiency of the proposed actions.

Methods for implementing the set tasks include methods of analysis of properties and opportunities for improvement of complex multi-functional systems, such as statical and systematic methods, mathematical methods, computational methods, probability theory, data processing theory with regard to research results, and information technologies.

Results and discussion

The Driver–Vehicle–Road–Environment (DVRE) system operates due to dynamic road infrastructure parameters and environmental conditions, motor vehicles' specifications and processes, psychophysiological state of drivers, and continuous system monitoring of changing processes. The main task of such system monitoring is to prevent road accidents and reduce severity of their consequences. As known, a road accident is a complex mechanism of interaction between "Vehicle–Vehicle", "Vehicle–Road", "Vehicle–Pedestrian", and "Vehicle–Environment" subsystems. Circumstances, causes and factors of road accidents are examined at the global expert level.

Road accident rate statistics are analyzed with an analytical approach including the safety factor method, accident rate factor method, and black spot identification method (Table 1).

Table 1. Methods applied to analyze "Vehicle–Road" subsystem parameters with an analytical approach

No	Method	Characterizing parameters	Analyzed "Vehicle–Road" subsystem parameters
1	Safety factor method	Maximum traffic speed at the analyzed motor road segment — $V_{\max}^{traffic}$ vehicle's initial speed — $V_{initial}$	Traffic intensity. Shoulder-to-shoulder width and width of shoulders. Clear vision distance (plan and profile views). Longitudinal grade. Curve radius in the road cross-section (on long ascending grades)
2	Accident rate factor method	Partial accident rate factors — K_i	Results of road accident statistical analysis. Traffic intensity. Shoulder-to-shoulder width and width of shoulders. Number of traffic lanes. Clear vision distance (plan and profile views). Longitudinal grade. Clear vision (plan and profile views). Vertical curves (plan view). Grade separation. Road surface condition.
3	Black spot identification method	Absolute and relative number of road accidents	Traffic intensity. Results of road accidents with injuries.

In the field of road construction, motor road operation and reconstruction, it is necessary to take into account the system of parametric characteristics of objects and conditions for their existence:

− geometry of road environment facilities (GREF);

− transport and operating conditions (TrOC);

− technical and operating conditions (TechOC);

− characteristics of road infrastructure facilities (CRIF).

Obtaining information about GREF, TrOC, TechOC, and CRIF is possible by means of diagnostic and computational methods of obtaining and processing

DOI: 10.23968/2500-0055-2018-3-1-29-37

of parametric characteristics (Kurakina, Evtyukov, 2017; Kurakina, 2014, 2016; Kurakina, Evtyukov, 2015, ROSDORNII, 2015) (Table 2).

Table 2. Methods applied to analyze parameters with diagnostic and computational methods

Diagnostic method			
1	Systematic monitoring	Usability of motor roads. Specified time intervals.	Shoulder-to-shoulder width and width of shoulders. Clear vision distance (plan and profile views). Longitudinal grade. Clear vision (plan and profile views). Vertical curves (plan view). Curve radii. Road surface evenness and strength. Adhesion characteristics.
2	Method for determination of transverse evenness of the road surface	Clearance between the road surface and the bottom surface of the leveling beam; clearance between the road surface and the profilograph wheel.	Road surface evenness. Rutting.
3	Dynamometer method for determining evenness of the road surface	Clearance between the road surface and the PKRS-2U (evenness and adhesion inspection tool with an oscillograph) wheel	Road surface evenness.
4	Method for determining the road/tire adhesion coefficient	Maximum rim pull. Vertical load on the road surface. Registration using PPK, IKSp-m (portable instruments for adhesion coefficient measuring).	Adhesion coefficient
5	Method for determining roughness of the road surface	Average valley depth	Valley depth roughness affecting the adhesion coefficient
6	Georadar sounding of road structure	Georadar profile with road structure density fluctuations	Depth of road structural layers. Landslide curve location.
7	Method for determining strength of the road structure	Elastic deflection value. Area of contact with the road surface. Falling weight characteristics.	Road surface strength and reliability. Elastic deflection of the road structure.
8	Core sampling method	Elastic deflection value. Drilling bit characteristics.	Road surface strength and reliability. Elastic deflection of the road structure.
Computational method			
1	Automated calculation and analysis	Computational software	Transport, technical and operating parameters. Road accident registration and analysis.
2	Method of panoramic video shooting of motor roads	Specifications of digital cameras, performed linear measurements	Shoulder-to-shoulder width and width of shoulders. Availability of cracks, potholes, and other types of damage in the road surface.

Mathematically, the model of expert study implementation with account for parameters can be represented in the following form:

$$Y = f(X), \quad (1)$$

where X — parameters applied and obtained during the study.

Taking into account methods of obtaining and processing of parameters during the study, the value X of the sum of all characteristics and conditions can be represented in the following form:

$$\left\{ \begin{array}{l} \sum_{i=1}^{n} X^A = f(x_i^A), \\ \sum_{i=1}^{n} X^D = f(x_i^D), \\ \sum_{i=1}^{n} X^C = f(x_i^C) \end{array} \right\}, \quad (2)$$

where $f(x_i^A)$ are parameters, their characteristics and conditions determined analytically, i.e. $f(x_i^D)$ are determined diagnostically and $f(x_i^C)$ are determined with computational methods, i is the number of obtained values of the studied parameters.

Taking into account equation 2, we obtain a set of values of parameters, obtained during studies with analytical, diagnostic and computational methods.

Therefore, taking into account equation 1 and parameters to be determined, the accounting during the expert study, involving numerous parameter values,

will be characterized by parameters involved in the study.

Evaluation of parametric characteristics of objects and conditions represents an expert opinion on the results of the study aimed at the following:

− accident rate at the analyzed road section;

− black spot identification on motor roads;

− identification of "weak" motor road segments to determine the qualitative component of the road infrastructure, in particular, the load-bearing capacity of the road structure. Identification of road surface defects, deflections, and moduli of elasticity to determine its remaining life.

− development of an automated road data base (ARDB) on “weak” motor road segments to raise awareness and improve expert study quality;

− compliance of the obtained values of vehicle and road infrastructure condition parameters with the requirements of regulatory documents;

− determination of road accident risks.

The dependence of the study, conducted by a diagnostic method, during which condition parameters were determined, has the following form:

$$\begin{aligned}&\mathrm{Y}(X^D) = f(N_i, W_{pull.}, W^{sh.}_{m\arg.}, W^{cent.}_{div.str.},\\ &S^{sh}_{m\arg}, L_{stop.}, i, i_{trans}, i_r, R_{curve}, S_{cl}, R_{convex}, R_{concave},\\ &Z, h_f, \angle_{slope}, I_{veh}, M_1 \div O_2, V_a, G_{veh}, K_P^{I-V},\\ &N_{acc}, ACC_{abs}, ACC_{rel}, \phi, t, r, r_h, E,\\ &D_{r.s.}, T_{a.s.}, T_{drain}, T^{signs}_{loc}, T_{light}, \grave{O}_{rail}, MTORT),\end{aligned} \quad (3)$$

where N_i is the number of lanes;

W_{pull} is the pullover width;

$W^{sh}_{m\arg}$ is the width of the margin strip of the shoulder, m;

$W^{cent}_{div.str.}$ is the width of the central dividing strip, m;

$S^{sh}_{m\arg}$ is the margin strip of the shoulder, m;

L_{stop} is the stopping strip, m;

i is the longitudinal grade, per mille;

i_{trans} is the transverse grade, per mille;

i_r is the raised curve grade, per mille;

R_{curve} is the curve radii in plan, m;

S_{cl} is the clear vision distance to the object, m;

R_{convex} is the radii of convex curves in profile, m;

$R_{concave}$ is the radii of convene curves in profile, m;

Z is the structure of the road bed;

h_f is the depth of fill, m;

h_e is the depth of excavations, m;

$\angle_{slope}$ is the slope grade;

I_{veh} is traffic intensity, vehicles/day;

$M_1 \div O_2$ the categories of vehicles from M_1 to O_2;

V_a is the vehicle speed, km/h;

G_{veh} is the vehicle mass, t;

K_P^{I-V} is the coefficient of braking performance of the vehicle;

N_{acc} is the number of road accidents;

ACC_{abs} is the absolute accident rate;

ACC_{rel} is the relative accident rate;

φ is the road/tire adhesion coefficient;

t is the rut depth (road surface rutting (wheel tracking)), cm;

r is the roughness of the road surface, average height of material projection, μm;

r_h is the hydraulic roughness;

E is the modulus of elasticity, MPa;

$D_{r.s.}$ are defects of the road surface;

$T_{a.s.}$ are artificial structures;

T_{drain} is the condition of the drainage system;

T^{signs}_{loc} is presence of driver location signs;

T_{light} is availability of lighting;

T_{rail} is presence of railway crossings;

$MTORT$ is equipping with technical means of road traffic organization.

The algorithm of the study on the analyzed system is presented in Figure 1.

DOI: 10.23968/2500-0055-2018-3-1-29-37

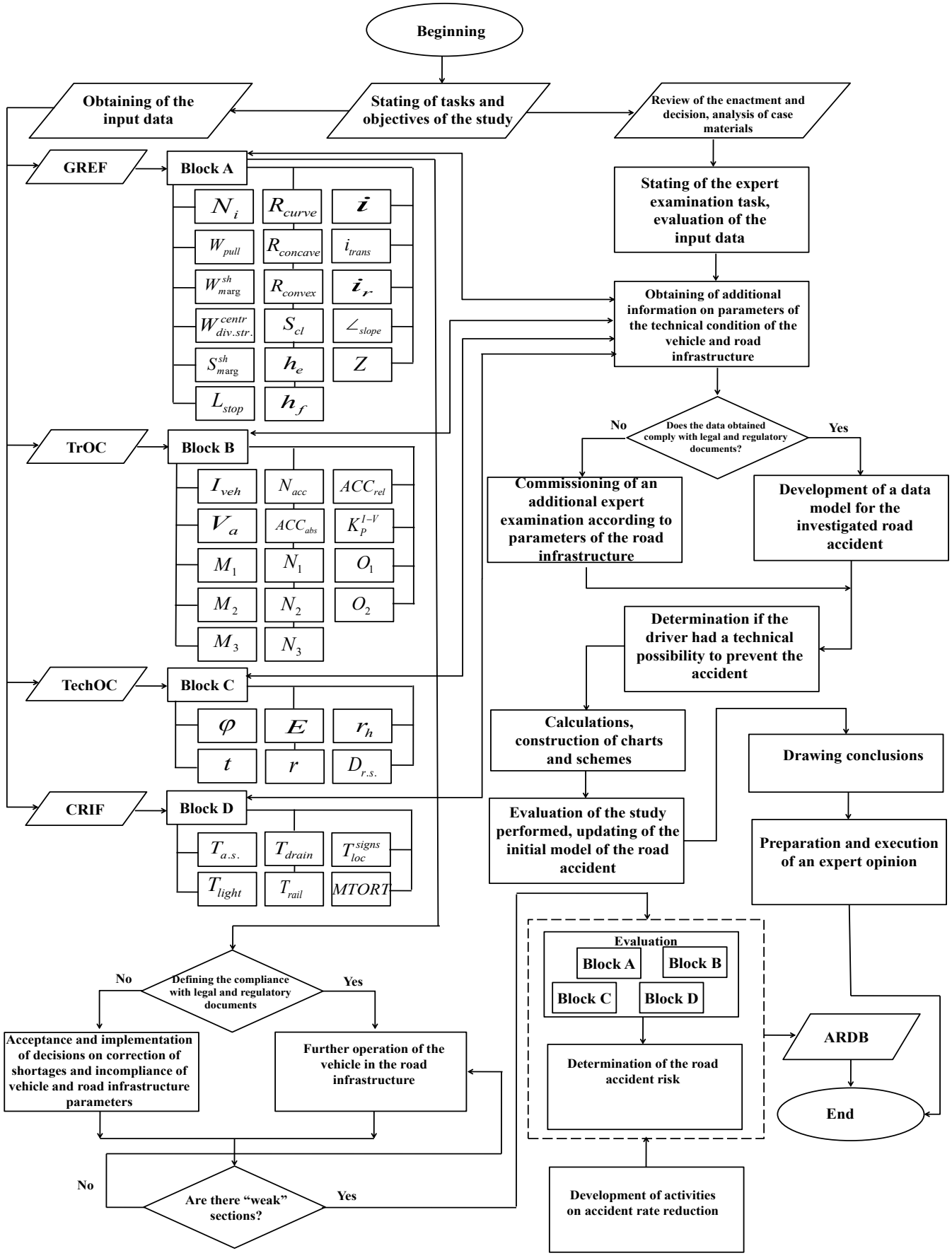

Figure 1. Algorithm of the study on the road infrastructure parameters' condition

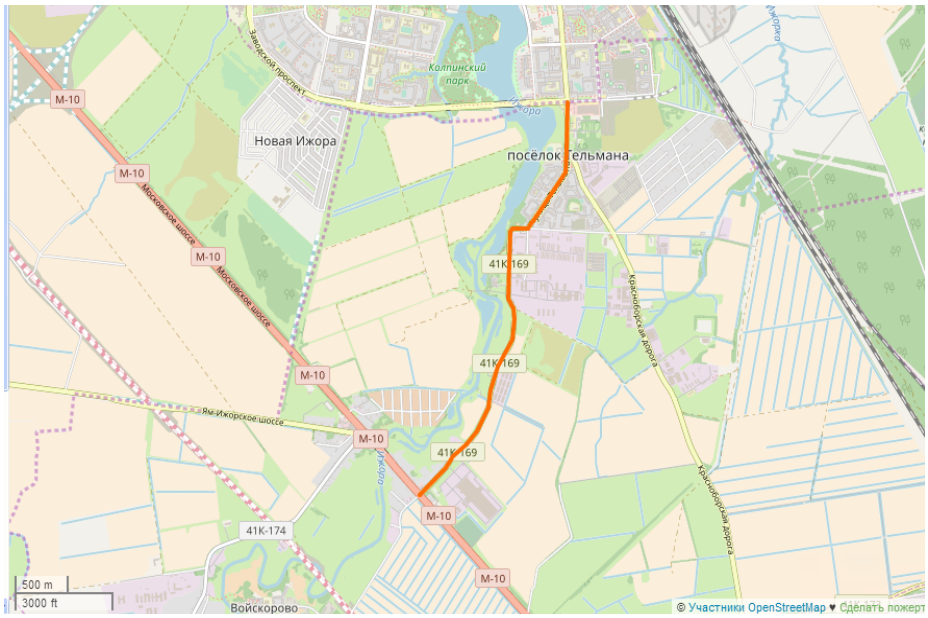

Figure 2. Location of the "Approach to Kolpino" road running in the Tosno District

The development of actions aimed at the improvement of road infrastructure parameters through traffic safety enhancement, as well as actions aimed at the reconstruction of the motor road or project-supported construction of road segments, is illustrated by an example of the "Approach to Kolpino" motor road segment.

The "Approach to Kolpino" regional public road running across the territory of the Tosno District (Figure 2). Length — 4,065 km (road No. 41K-169). An entrance from the Kolpino District of Saint Petersburg to the Russia M-10 federal public road (Moscow–Tver–Veliky Novgorod–SPb)

In 2016, 7 registered road accidents with injuries occurred on the "Approach to Kolpino" road, 1 accident cluster (black spot) was distinguished for analysis.

A list of actions aimed at black spot elimination was developed.

The corresponding actions were classified into three categories: low-cost, medium-cost and high-cost actions.

Table 3 presents general data on black spots where accidents with injuries occurred during the analyzed period.

Table 3. Condition of parameters at the "Approach to Kolpino" road segment

Black spot address								
Motor road			Start of the segment, km + m		End of the segment, km + m		Length of the segment, m	
"Approach to Kolpino"			3 + 400		4 + 400		1,000	
Black spot characteristics								
No	Date	Time	Type	Location, km + m	Injured			Poor road conditions
					Fatalities	Injuries		
						Total	incl. children with injuries	
1	10.06.2016	10:25	Vehicle/pedestrian accident	3 + 900	1	–	–	Absence or poor visibility of horizontal signalization
2	18.02.2016	8:00	Vehicle/pedestrian accident	3 + 440	–	1	1	Absence or poor visibility of horizontal signalization
3	20.10.2016	18:10	Collision with a standing vehicle	3 + 820	–	1	–	Absence of shortcomings in transport and operating conditions of the roadway
4	28.08.2016	18:20	Vehicle/pedestrian accident	3 + 400	–	1	1	Absence or poor visibility of horizontal signalization
5	23.09.2016	20:40	Vehicle/bicycle accident	4 + 030	–	1	–	Absence or poor visibility of horizontal signalization

DOI: 10.23968/2500-0055-2018-3-1-29-37

Table 4. Data on black spots on the "Approach to Kolpino" road 3 + 400 – 4 + 400

"Approach to Kolpino" road 3 + 900 — vehicle/pedestrian accident	
Traffic violation / concurrent traffic violations	Jaywalking with a crosswalk in sight or an underground (ground level) crosswalk in close vicinity
Street and road network facilities	Road section
Road conditions:	
weather conditions	Clear weather
roadway condition	Dry
lighting	Day-time
"Approach to Kolpino" road 3 + 440 — vehicle/pedestrian accident	
Traffic violation / concurrent traffic violations	Jaywalking with a crosswalk in sight or an underground (ground level) crosswalk in close vicinity
Street and road network facilities	Road section
Road conditions:	
weather conditions	Clear weather
roadway condition	Treated with deicing agents
lighting	Day-time
"Approach to Kolpino" road 3 + 820 — collision with a standing vehicle	
Traffic violation / concurrent traffic violations	Failure to keep distance
Street and road network facilities	Road section
Road conditions:	
weather conditions	Clear weather
roadway condition	Dry
lighting	Day-time
"Approach to Kolpino" road 3 + 400 — vehicle/pedestrian accident	
Traffic violation / concurrent traffic violations	Violation of rules for driving across the crosswalk / non-compliance with mandatory vehicle insurance requirements
Street and road network facilities	Unsignalized crosswalk
Road conditions:	
weather conditions	Clear weather
roadway condition	Dry
lighting	Day-time
"Approach to Kolpino" road 4 + 030 — vehicle/bicycle accident	
Traffic violation / concurrent traffic violations	Disregard of priority rules/violation of vehicle arrangement on the roadway/alcohol-impaired driving
Street and road network facilities	Departure from the adjacent territory
Road conditions:	
weather conditions	Clear weather
roadway condition	Dry
lighting	Night-time, lighting is on

Results of full-scale study of the black spot on the "Approach to Kolpino" road 3 + 400 – 4 + 400

1. Low quality of shoulder maintenance, availability of potholes filled with water.
2. Road surface shortcomings and defects, rutting.
3. Absence or poor visibility of horizontal signalization.
4. Traffic signalization is maintained on the road segment.

Actions aimed at elimination of the black spot on the "Approach to Kolpino" road 3 + 400 – 4 + 400 were developed.

For elimination of black spots, the following priority actions were developed with expected accident rate reduction (%) as a result of their implementation:

– installation of priority traffic signs, prohibitory signs and warning signs for speed reduction, informing of approach to a crosswalk, children crossing zone, dangerous corner — 34%;

– marking of horizontal signalization with wear-resistant materials;

– marking of prohibitory and warning signs on the road surface;

– installation of traffic lights T.7 in zones where pedestrians cross the roadway, marked with horizontal signalization 1.14.1 and traffic signs 5.19.1, 5.19.2 "Crosswalk" to increase focus of drivers when approaching a crosswalk and raise their vigilance upon its passage — 10%;

– arrangement of sidewalks to improve pedestrian traffic safety and avoid vehicle/pedestrian accidents — 23%;

– arrangement of guardrails along sidewalks, in pick-up and drop-off areas, in crosswalk areas to avoid vehicle/pedestrian accidents and ensure safe pedestrian traffic — 25%.

Priority forward-looking actions:

– arrangement of lighting along the road and in pedestrian traffic zones to improve visibility and detection of vertical and horizontal signalization — 25%;

– road surface restoration (road paving) — 21% in case of 2 lanes, 59% in case of more than 2 lanes.

Mandatory actions aimed at traffic safety improvement shall comply with the GOST R 50597 requirements to operating conditions acceptable in a safe traffic environment.

Efficiency of the proposed actions is described in Table 4 (with account for low-, medium- and high-cost actions). Changes in condition parameters after implementation of actions at the black spot of the "Approach to Kolpino" road 3 + 400 – 4 + 400 are assessed.

Table 5. Efficiency of the proposed actions

Low-cost actions	Costs: 151,212.44
Approximate assessment of impact, reduction in the number of registered road accidents	-41%
Expected annual effect in case of implementation of actions; reduction by:	0.41 fatalities
	1.64 non-fatal injuries
Annual savings in case of road accident prevention	7.71 mln RUB
Payback period	0.3 months
Medium-cost actions	Costs: 4,617,134.44
Approximate assessment of impact, reduction in the number of registered road accidents	-68%
Expected annual effect in case of implementation of actions; reduction by:	0.68 fatalities
	2.72 non-fatal injuries
Annual savings in case of road accident prevention	12.84 mln RUB
Payback period	4.3 months
High-cost actions	Costs: 14,933,319.84
Approximate assessment of impact, reduction in the number of registered road accidents	-93%
Expected annual effect in case of implementation of actions; reduction by:	0.93 fatalities
	3.72 non-fatal injuries
Annual savings in case of road accident prevention	17.56 mln RUB
Payback period	10 months

Conclusions

During road construction, it is necessary to follow construction regulations and take into account the relief and climate of the district. In the course of further road maintenance, condition of the following road infrastructure facilities' parameters shall be monitored: qualitative and quantitative characteristics of the traffic flow, vehicle braking processes, road structure strength as per the modulus of elasticity, identification of black spots as per the risk of their formation, their impact on accident rate prediction.

Analysis of the data obtained diagnostically and processed with analytical and computational methods allows obtaining actual results regarding traffic safety condition and compliance of parameters with applicable regulations. Obtaining actual results regarding parameters allows developing actions aimed at elimination of black spots and accident rate decrease. Such actions also allow predicting road accident risk formation, improving reliability of conclusions and accuracy of calculations in expert reports.

DOI: 10.23968/2500-0055-2018-3-1-29-37

References

Domke, E.R. (2012). *Rassledovanie i ekspertiza dorozhno-transportnykh proisshestvii [Investigation and expert examination of road accidents],* 2nd edition. Moscow: Publishing Center "Akademia", p. 288. (in Russian)

Evtyukov, S.A., Vasiliev, Ya.V. (2012). *Dorozhno-transportnye proisshestviia: rassledovanie, rekonstruktsiia, ekspertiza [Road accidents: investigation, reconstruction, expert examination].* Saint Petersburg: Publishing House "DNK", p. 392. (in Russian)

Federal State Budgetary Institution ROSDORNII (2015). *Rekomendatcii po uchetu i analizu dorozhno-transportnykh proisshestvii na avtomobilnykh dorogakh Rossiiskoi Federatcii. ODM 218.6.015-2015 [Recommendations for accounting and analysis of road accidents on the roads of the Russian Federation. ODM 218.6.015-2015].* (in Russian)

Ilarionov, V.A. (1989). *Ekspertiza dorozhno-transportnykh proisshestvii [Expert examination of road accidents].* Moscow: Transport, p. 255. (in Russian)

Kurakina, E.V., Evtyukov, S.A. (2014). Sovershenstvovanie algoritma avtotekhnicheskoi ekspertizy pri rekonstruktsii DTP, uchityvaiushchei tekhnicheskoe sostoianie transportnogo sredstva i dorogi [Improvement of the algorithm of technical expert examination of motor vehicles during reconstruction of road accidents with account for the technical condition of vehicles and roads]. In: *Proceedings of the 11th International Conference "Organization and Traffic Safety Management in large cities"*, pp. 518–527. (in Russian)

Kurakina, E.V., Evtyukov, S.A. (2015). Issledovanie stcepnykh kharakteristik dorozhnogo pokrytiia pri avtotekhnicheskoi ekspertize DTP [Analysis of adhesion characteristics of road surfaces during technical expert examination of motor vehicles upon road accidents]. *Vestnik grazhdanskikh inzhenerov [Bulletin of Civil Engineers]*, 5 (52), pp. 216–223. (in Russian)

Kurakina, E.V., Evtyukov, S.A. (2017). Improvement of the system for accounting of parameters during construction of motor roads. Architecture and Engineering, 2(3), pp. 34–42. DOI: 10.23968/2500-0055-2017-2-3-34-42

Kurakina E.V., Evtyukov S.S., Golov E.V. (2017). *Rekonstruktciia dorozhno-transportnykh proisshestvii [Reconstruction of road accidents].* Saint Petersburg: Publishing House “Petropolis”. (in Russian)

Kurakina, E., Evtyukov, S., Lukinskiy, V., Ushakov, A. (2017). Methodology for the reconstruction and investigation of causes of accidents in the parameters of vehicle condition and road environment. *Transportation Research Procedia*, 20, pp. 185–192. DOI: 10.1016/j.trpro.2017.01.049

Kurakina, E.V. (2013). Ekspertnaia kharakteristika avtomobilnoi dorogi v dorozhno-transportnoi ekspertize [Expert review of roads in road traffic expert examination]. *Modern problems of science and education*, 5. Available at: http: //www.science-education.ru/111-r10273 (accessed on: 29.01.2018). (in Russian)

Kurakina, E.V. (2014a) *Nauchno-metodicheskoe obespechenie avtotekhnicheskoi ekspertizy, uchityvaiushchei tekhnicheskoe sostoianie avtomobilia i dorozhnoi sredy [Scientific and methodological support of technical expert examination of motor vehicles with account for the technical condition of vehicles and road environment].* PhD Thesis in Engineering. Saint Petersburg, p. 203. (in Russian)

Kurakina, E.V. (2014b). Issledovanie sostoianiia bezopasnosti i kachestva podsistemy [Investigation of safety and quality of the "Road" subsystem]. In: *Proceedings of the International Scientific and Technical Conference "Engineering Science 2014: theory, education, practice and innovations"*, pp. 232–244. (in Russian)

Kurakina, E.V. (2014c). Ob otklonenii normativnykh kharakteristik pokazatelei avtomobil'noi dorogi (na primere avariino-opasnykh uchastkov dorog Leningradskoi oblasti) [On deviations of standard characteristics of the road (case study of accident clusters of roads in the Leningrad Region)]. *Modern problems of science and education*, 2, p. 118. (in Russian)

Kurakina, E. V. (2016). Diagnosticheskoe issledovanie elementov avtomobil'nykh dorog na uchastkakh DTP nerazrushaiushchim kontrolem [Diagnostic work-up of the motor road elements at the site of traffic accident by nondestructive testing technique]. *Vestnik grazhdanskikh inzhenerov [Bulletin of Civil Engineers]*, 6 (59), pp. 231–237. (in Russian)

Kurakina, E. V. (2017). Sovershenstvovanie algoritma dorozhno-transportnogo issledovaniia nerazrushaiushchim metodom [Improvement of the algorithm of road and transport investigation in a non-destructive method]. *Vestnik grazhdanskikh inzhenerov [Bulletin of Civil Engineers]*, 1 (60), pp. 262–269. (in Russian)

Suvorov, Yu.B., Kikot, I.M., Khapatnyukovsky, M.V., Kovalenko, L.A., Kilienko, I.I. (1990). *Diagnosticheskoe issledovanie elementov avtomobil'nykh dorog na uchastkakh dorozhno – transportnykh proisshestvii (dorozhnykh uslovii), vliiaiushchikh na bezopasnost' dorozhnogo dvizheniia [Diagnostic study of road elements at sections of high accident rate (road conditions) affecting road safety].* Moscow: All-Union scientific research institute of judicial investigation, p. 96. (in Russian)

Vasiliev, A.P. (2005). *Spravochnaia entsiklopediia dorozhnika [Encyclopedia for road workers],* vol. 1. Moscow: Informavtodor. (in Russian)

STUDY OF AIR POLLUTION WITH COMBUSTION PRODUCTS OF GAS STOVES IN GAS-SUPPLIED APARTMENTS

Alexander Shkarovskiy [1,2], Agnieszka Maliszewska [2]

[1] Saint Petersburg State University of Architecture and Civil Engineering
Vtoraja Krasnoarmejskaja ul. 4, St. Petersburg, Russia

[2] Koszalin University of Technology,
Sniadeckich St. 2, 75-453 Koszalin, Poland

[1] szkarowski@mail.ru

Abstract

As opposed to other fuel combustion appliances, in case of gas stoves, combustion products are released directly into the apartment air. Some people actually spend much time in such environment. Therefore, even low concentrations of harmful substances emitted with combustion products can pose a threat to health and life of people. Maximum allowable concentration of harmful substances in the air was analyzed for various countries.

Theoretical calculations of possible content of nitrogen oxides (NO_x) in gas-supplied kitchens were performed. Actual NO_x content in the air was experimentally studied under various operating conditions of gas stoves and ventilation options. According to the study results, in most of the room, NO_x concentration at the height of breathing level of a standing person can exceed the allowable value for premises intended for permanent occupancy.

Keywords

Fuel combustion, combustion products, harmful substances, nitrogen oxides.

Introduction

The use of organic fuel is inextricably related to emissions of harmful substances contained in combustion products. In most cases, those products are released to the atmosphere through chimneys. Their release height can range from several meters to several hundred meters. Combustion products from household gas stoves are released directly into the air of premises. Some people actually spend much time in such environment. Therefore, even low concentrations of harmful substances emitted with combustion products can pose a threat to health and life of people. Gas equipment in apartments of various countries is very similar. For example, in the Russian Federation and Poland, gas equipment units are almost identical in performance. Therefore, results of studies carried out in Poland can be of great interest for specialists in other countries.

The development strategy of Poland implies intensive gas infrastructure development in populated areas. Such development results in the increasing number of households where energy demand (including that for cooking) will be supplied with gas fuel. The popularity of this initiative is confirmed by the fact that, since July 2016, the Polish Gas Company has signed more than 240 protocols of intent with local authorities regarding gas infrastructure development (Polska Spółka Gazownictwa, 2016).

In 1997, 56% of Polish households used natural gas stoves and about 14% of Polish households used liquefied gas stoves (Skowroński, 1997). In 2015, progress in gas supply was observed: almost 58% of households had dual gas and electric stoves (with an electric oven) and about 31% of households had gas stoves (Central Statistical Office, 2017).

The authors set a task to study the effect of harmful substances emitted with combustion products from gas stoves on the creation of the environment in the kitchen and the entire apartment.

Subject, tasks and methods

The subject of the study is a standard household gas stove. The aim is to study the effect of combustion products from such appliances, polluting the air in the kitchen and the entire apartment. If natural/liquefied gas stoves are in good technical state, the list of harmful substances contained in combustion products can be reduced to carbon monoxide and nitrogen oxides. As it was already mentioned above, even a small amount of

DOI: 10.23968/2500-0055-2018-3-1-38-43

those substances released directly into the kitchen air can be dangerous.

Toxic properties of carbon monoxide (CO) (carbon (II) oxide) are well known. Forming carboxyhemoglobin, CO blocks transportation of oxygen and cellular respiration in the human body. A significant amount of CO is formed upon incomplete fuel combustion, i. e. stove malfunctioning. But, as it was already mentioned above, even a small amount of harmful substances released directly into the kitchen air can be dangerous.

In fact, the contact of the flame with the cold bottom surface of cookware results in a small but stable amount of CO in combustion products. Therefore, the chain combustion reaction is interrupted leading to incomplete chemical combustion (incomplete combustion). Besides, misadjustment, contamination and wear of burner devices shall be taken into account.

Nitrogen oxides are one of the most dangerous pollutants. It is impossible to prevent their formation during fuel combustion. As for the maximum allowable concentration, those substances are way more dangerous than carbon monoxide.

Among compounds of this class, nitrogen monoxide (nitrogen (II) oxide) and nitrogen dioxide (nitrogen (IV) oxide) formed during fuel combustion are the most significant. The inevitability of their formation can be explained by high-temperature oxidation of air nitrogen during fuel combustion.

In this case, nitrogen monoxide (NO) is mainly formed, accounting for up to 95% of their total amount. NO falls into the category of irritating toxic substances. It has sharp odor, but it is much less dangerous than nitrogen dioxide (NO_2). As a very active radical, NO rapidly oxidizes to NO_2 in the air (up to 92% in 30 s).

Nitrogen dioxide is characterized by a wide range of harmful effects on both human and wildlife. As an acid-forming oxide, it participates in degradation of the natural environment and building structures. Nitrogen dioxide is essential to the phenomenon of photochemical smog, causing the formation of even more harmful chemical compounds.

The study included three successive stages with interrelated results:

- review, comparison and analysis of standards in various countries to establish the maximum allowable concentration of harmful substances in the air of residential premises and in combustion products from household gas stoves;
- theoretical studies and calculations of the possible emission level of harmful substances during gas stove operation;
- experimental studies of the actual level of air pollution in the kitchen.

Results

1. Review of the regulatory framework

According to the Polish standard for premises intended for permanent occupancy (Zarządzenie Ministra Zdrowia, 1996), maximum allowable concentrations are established only for 35 harmful substances. They do not include nitrogen monoxide, which, according to numerous studies (Miller, 1997, Bieniek, 2008, Logue et al., 2014), forms in hazardous amounts even during normal operation of gas stoves. Maximum allowable concentrations in working areas (Rozporządzenie Ministra Pracy, 2014) are established for 524 substances. Maximum allowable concentrations in the outdoor air established by a separate regulation (Rozporządzenie Ministra Środowiska, 2012).

The analysis of Polish standards describing maximum allowable concentrations of harmful substances typical for gas stove operation is given in Table 1.

Table 1. Maximum allowable concentrations of harmful substances according to Polish hygienic standards

Chemical compound, unit	Exposure time	Maximum allowable concentration (MAC)				
		Indoor environment			Outdoor environment	
		Premises intended for permanent occupancy, residential premises	Working premises			
			MAC_{wa}	MAC_{ms}	MAC_{da}	MAC_{ms}
Carbon monoxide, mg/m³	15 min	-		117	-	-
	30 min	10	-	-	-	-
	8 h	3 (daily average)	23	-	10	-
Nitrogen monoxide, µg/m³	15 min	-	-	7,000	-	-
	8 h	-	3,500	-	-	-
	1 year				30	
Nitrogen dioxide, µg/m³	15 min	-	-	1,500		-
	1 h	-	-	-	200	400
	8 h	-	700	-	-	-
	1 year	-	-	-	40	-

Notes: MAC_{wa} — MAC in the working area; MAC_{ms} — maximum single allowable concentration; MAC_{da} — daily average MAC.

A similar analysis was also carried out based on the results of the review of hygienic standards of the World Health Organization (WHO), some European countries and their separate regions, in the proceedings of the scientific workshop (Santarsiero, 2015). The comparable data are given in Table 2.

Obviously, the analysis of similar Russian standards is of great interest as well.

In the Russian Federation, maximum allowable concentrations of harmful substances in the outdoor air are established by the Hygienic Standard GN 2.1.6.1338-03 "Maximum allowable concentrations (MAC) of pollutants in the outdoor air of populated areas". For carbon monoxide, MAC_{ms} = 5 mg/m^3; MAC_{da} = 3 mg/m^3. For nitrogen monoxide, MAC_{ms} = 0.4 mg/m^3; MAC_{da} = 0.06 mg/m^3. For nitrogen dioxide, MAC_{ms} = 0.085 mg/m^3; MAC_{da} = 0.04 mg/m^3.

Since the adoption of the document followed by subsequent changes, the standard for nitrogen dioxide was at some point removed (considered repealed), and at another point it significantly decreased to the WHO standard (0.2 mg/m^3 within 1 hour, see Table 2), and then returned to its original value.

It should be noted that the current Russian standard for the outdoor air is the tightest in comparison with all standards known to the authors. However, regarding the considered issue, it is more important to analyze standards for the indoor air. Russian standards do not specify the requirements to the air in residential premises. SanPiN (Sanitary Rules and Regulations) 2.1.2.1002-00 "Sanitary and epidemiological requirements to residential buildings and premises" describes only concentrations of chemical substances in the air of residential premises "upon their commissioning".

This well-known passive requirement provides only for the absence of emissions from building and finishing materials in comparison with the background concentration in the outdoor air.

Therefore, it was decided to rely on the values established by the Hygienic Standard GN 2.2.5.1313-03 "Chemical factors of the production environment. Maximum allowable concentrations (MAC) of harmful substances in the air of working areas".

The corresponding value for nitrogen monoxide is absent in the standard. MAC_{ms} for NO_2 and NO_x (expressed as NO_2) are given: 2 mg/m^3 and 5 mg/m^3, respectively.

It is difficult to understand the difference between those two parameters, but the NO_2 standard can only be compared with the equivalent Polish standard — 1.5 mg/m^3 in 15 min.

As for the MAC for carbon monoxide, there is an apparent discrepancy in the standard. On the one hand, if some value is given, then it is MACms in accordance with the notes to the table of values.

Table 2. Maximum allowable concentrations of harmful substances in some European countries (Polish Committee for Standardization, 2000)

Chemical compound	WHO		France	Germany		Nether-lands	Great Britain	Belgium (Flan-ders)	Portugal	Norway
	Indoor environ-ment	Outdoor air								
CO mg/m^3	100 (15 min)	100 (15 min)	100 (15 min)	-	-	100 (15 min)	100 (15 min)	-	10 (8 h)	-
	60 (0.5 h)	-	60 (0.5 h)	6* (0.5 h)	60** (0.5 h)	60 (0.5 h)	60 (0.5 h)	-	-	-
	30 (1 h)	35 (1 h)	30 (1 h)			30 (1 h)	30 (1 h)	30 (1 h)	-	25 (1 h)
	10 (8 h)	10 (8 h)	10 (8 h)	1.5* (8 h)	15** (8 h)	10 (8 h)	10 (8 h)	-	-	10 (8 h)
	-	7 (24 h)	-	-	-	-	-	5.7 (24 h)	-	-
NO_2 µg/m^3	-	-	-	350** (0.5 h)	-	-	-	-	-	
	200 (1 h)	200 (1 h)	200 (1 h)	-		200 (1 h)	300 (1 h)	135 (1 h) VI: 200 (1 h)	-	200 (1 h)
	40 (1 year)	40 (1 year)	40 (1 year)	60 (1 year)		40 (1 year)	40 (1 year)	-	-	-
	-	-	-	-	-	-	-		100 (24 h)	

*RWI: concentration of a particular substance for which there is no evidence of adverse health effects (according to the present scientific data).

**RWII: concentration of a substance with health effects (requires immediate actions).

DOI: 10.23968/2500-0055-2018-3-1-38-43

But, on the other hand, the value stated for CO (20 mg/m^3) is accompanied by comments that the value can increase accordingly upon less long exposure time (1 h, 0.5 h, 15 min). Therefore, it is actually the MAC_{wa} value which is comparable with values in most countries (e.g., in Poland, it amounts to 23 mg/m^3).

The authors chose standard values to use in studies on the basis of the following considerations. People spend so much time in residential premises that it can be comparable with time spent in a working area. However, the average operating time of a gas stove rarely exceeds 1 hour, therefore, it is reasonable to use an intermediate value. In Polish standards, regarding NO2 concentration, it varies from 0.7 to 1.5 mg/m^3, and in Russian standards, it should be less than 2.0 mg/m^3 taking into account the only stated value.

2. Theoretical calculations

In Poland, only CO concentration at a height of 10 mm above stove burners is measured during the annual leakage monitoring of the internal gas supply system. No similar requirements for nitrogen oxides are found. No standard values for their concentration in combustion products of household gas stove burners are set. Therefore, it was decided to use the Russian experience.

The Soviet GOST 10798-85 "Household gas stoves. General specifications" specified requirements for the *quality of gas combustion*, according to which the concentration of *nitrogen oxides in combustion products* should not exceed 200 mg/m^3. The first Russian GOST R 50696-94 under the same name retained the wording and standard values. However, an inexplicable change took place upon further development of the regulatory framework. In the applicable GOST R 50696-2006 (Federal Agency, 2006), the concept of *"combustion quality"* is replaced with *"combustion efficiency"*, while the only requirement for the composition of combustion products refers to carbon monoxide. Nitrogen oxides are not even mentioned in this document.

No other requirements for the concentration of nitrogen oxides in combustion products of household gas stove burners were found. Therefore, it was decided to use historical Soviet standard values in theoretical calculations. It is difficult to separate processes of combustion products' formation from their continuous mixing with the ambient air when burners operate directly in the open space of the kitchen. However, the standard value mentioned above allows assessing the NO_x concentration in the kitchen air. To do that, it is sufficient to use characteristics of burners and standard requirements for ventilation of rooms.

If two burners (medium and large) operate simultaneously with the rated power of 1.90 kW and 3.00 kW, the gas flow rate with the net calorific value of 37.60 MJ/m^3 will be as follows:

$$\frac{(1.9+3.0)10^3 3600}{37.6\cdot 10^6} = 0.469 \ \text{m}^3/\text{h}.$$

The selected standard value of the NO_x concentration in combustion products (200 mg/m^3) refers to dry undiluted products, i.e. to the excess air factor **α** = 1.0. Then, upon the theoretical specific volume of dry combustion products of 8.52 m^3/m^3 of gas (Szkarowski, 2014), the flow of combustion products released into the room can be estimated as follows:

$$0.469 \cdot 8.52 = 3.996 \ \text{m}^3/\text{h}.$$

Therefore, the amount of nitrogen oxides released into the kitchen air will be as follows:

$$3.996 \cdot 200 = 799.2 \ \text{mg/h}.$$

Since the estimated air exchange in a gas-supplied kitchen with a window should be at least 70 m^3/h (Polish Committee for Standardization, 2000), it is possible to give a rough estimate of the NO_x concentration directly in the air of the room:

$$\frac{799.2}{70} = 11.42 \ \text{mg/m}^3.$$

If the Russian standard value for air exchange (90 m^3/h) was used, the result would be somewhat lower (8.88 mg/m^3).

Anyway, the results obtained are disappointing. Due to the lack of any standard values for residential premises, the result can only be compared with standard values for working premises in the range from MAC_{ms} to MAC_{wa}. The concentration estimate obtained with a number of lowering assumptions exceeded even the hard-to-explain value of MAC_{ms} = 7 mg/m^3 for NO taken from the Polish standard (see Table 1). The Polish value of MAC_{wa} for NO_2 (0.7 mg/m^3) was exceeded manifold. The Russian standard value of MAC_{ms} for NO_x (5 mg/m^3) was also exceeded, but it is the maximum single concentration. A person can stay in the kitchen for much longer time than the exposure time established by that value, i.e. 15 minutes.

According to numerous data, the NO_x concentration of 15 mg/m^3 is an extreme value that can be considered relatively safe for people in case of short exposure time. Effects of nitrogen oxides on bronchitis morbidity in children were observed even at concentrations less than 1 mg/m^3. These facts substantiated the need for experimental studies.

3. Experimental studies

Measurements were carried out in a kitchen with an area of 6.90 m^2 in an apartment located on the 6th floor of a standard large-panel 9-story building. The kitchen is equipped with a standard 4-burner Gorenje gas stove with an oven. The burner capacity and flow rate of natural gas with a high content of methane are as follows (given the Wobbe number is within Wo = 45.7...54.7 MJ/m^3):

- small burner — 1 kW (79.6 l/h);
- two medium burners — 1.9 kW (151.3 l/h);
- large burner and oven burner — 3.0 kW (238.9 l/h).

A 14x14 cm ventilation duct is embedded in a kitchen wall, providing specified natural air extraction. A 172x142 cm tilt-and-turn window is located in the wall opposite to the gas stove. A refrigerator and a standard kitchen unit are also located in the kitchen.

The composition of the air undergoes dynamic changes during the operation of the gas stove. Therefore, a real-time measurement method was chosen for the studies. The Testo-33 gas analyzer for combustion products (TESTOTERM), meeting the requirements of the Polish standard PN-EN 482: 2002, was used.

Measurements by grid points in increments of 10 cm in plan view and in increments of 5 cm in height were carried out; the obtained values were averaged within the range of the standard height of breathing level of an adult standing person (1.50–1.75 m). The measurements were arranged using standard planning methods for experiments.

The experimental results obtained are presented in Table 3 and in Figure 1. According to those results, high concentrations of nitrogen oxides (up to 20 mg/m^3) form at the height of breathing level in most of the kitchen under normal operating conditions of the gas stove. This value is significantly higher than the maximum single allowable concentration of NO_x specified in standards of various countries (e.g. 5 mg/m^3 in Russian standards). At the same time, carbon monoxide in the amount up to 5 mg/m^3 is present in the air.

Table 3. Summary data on NOx concentrations in the kitchen air

No.	Experimental conditions	NO_x concentration (expressed as NO_2), mg/m^3, along isolines with the following marks				
		○	●	⁎	▲	Δ
1	Four burners are operating (7.8 kW), or the medium and large burners and oven burner are operating (7.9 kW). The door and the window leaf are open	20	10	5	3	1
2	Two medium burners are operating (3.8 kW), or the small burner and oven burner are operating (4.0 kW). The door and the window leaf are open	13	6	4	2	<1
3	Two medium burners are operating (3.8 kW), or the small burner and oven burner are operating (4.0 kW). The door and the window leaf are closed	18	9	5	4	1

Notes:

1. Measurements under conditions 2 and 3 were carried out by isolines determined under the conditions of the first experiment.

2. The absolute maximum concentration was recorded under conditions 1, at a height of 1.65 m from the floor marked in the scheme, and totaled 28 mg/m^3.

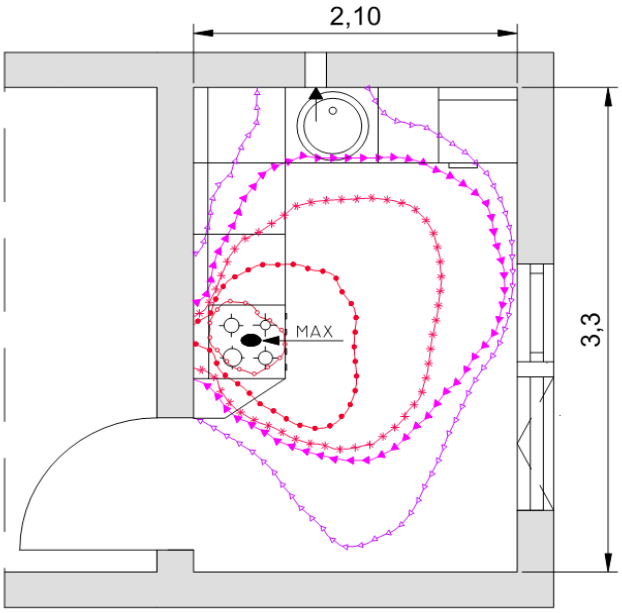

Figure 1. Isolines of nitrogen oxides' concentrations in the kitchen air

Conclusions

1. Combustion products of household gas stoves are released directly into the air of residential premises, where people spend much time.

In this case, nitrogen oxides inevitably forming upon combustion of organic fuels are main harmful substances. Standard values for the NO_x concentration in combustion products or in the apartment air are not specified.

2. Theoretical calculations revealed possible formation of NOx high concentrations in the air of a gas-supplied kitchen. The various standard values, analyzed in the study, may be exceeded several-fold and more in the air of the working area and in the outdoor air.

The experimental studies confirmed those calculations. The NO_x concentration in the air of a standard kitchen exceeds all standard values known to the authors several-fold even in case of short exposure time (up to 15 min).

3. Long stay in an environment contaminated with nitrogen oxides poses a threat to health and requires immediate actions of specialists.

On the one hand, it is necessary to introduce regulations for the concentration of harmful substances in the air of residential premises.

Secondly, technical actions shall be taken to improve ventilation of gas-supplied apartments.

DOI: 10.23968/2500-0055-2018-3-1-38-43

References

Bieniek, M. (2008). Wpływ tlenków azotu na jakość powietrza w pomieszczeniach [The influence of nitrogen oxides on indoor air quality]. *Prace naukowe GIG Górnictwo i Środowisko [Scientific papers of GIG Gornictwo i Srodowisko],* 2, pp.2–17. (in Polish)

Central Statistical Office (2017). *Zużycie energii w gospodarstwach domowych w 2015 r [Energy consumption in households in 2015].* Available at: https://stat.gov.pl/files/gfx/portalinformacyjny/pl/defaultaktualnosci/5485/2/3/1/zuzycie_energii_w_gospodarstwach_domowych_w_2015_r..pdf (accessed on: 21.01.2018) (in Polish)

Federal Agency on Technical Regulating and Metrology (2006). *GOST R 50696-2006: Pribory gazovye bytovye dlia prigotovleniia pishchi. Obshchie tekhnicheskie trebovaniia i metody ispytanii [GOST R 50696-2006: household gas cooking appliances. General technical requirements and test methods].* Moscow: Rosstandart. (in Russian)

Logue, J.M., Klepeis, N.E., Lobscheid, A.B., Singer, B.C. (2014). Pollutant Exposures from Natural Gas Cooking Burners: A Simulation-Based Assessment from Southern California. *Environ Health Perspectives,* 122(1), pp.43–50. DOI: 10.1289/ehp.1306673

Miller, R. (1997). Badanie emisji zanieczyszczeń z kuchenek gazowych [Examination of pollutant emissions from gas stoves]. *Ochrona Środowiska [Environmental Protection]*, 1(64), pp.33–37. (in Polish)

Minister of the Environment (2012). *W sprawie poziomów niektórych substancji w powietrzu [On the levels of certain substances in the air*]. (in Polish)

Minister of Health and Social Welfare (1996). *W sprawie dopuszczalnych stężeń i natężeń czynników szkodliwych dla zdrowia, wydzielanych przez materiały budowlane, urządzenia i elementy wyposażenia w pomieszczeniach przeznaczonych na pobyt ludzi [The permissible concentrations and intensities of factors harmful to health, emitted by construction materials, devices and elements of equipment in rooms intended for human stay]* (in Polish)

Minister of Labor and Social Policy (2014). *W sprawie najwyższych dopuszczalnych stężeń i natężeń czynników szkodliwych dla zdrowia w środowisku pracy [On the highest allowable concentrations and intensities of factors harmful to health in the work environment]*. Warsaw. (in Polish)

Polska Spółka Gazownictwa (2016). *Strategia rozwoju na lata 2016–2022 [Development strategy for 2016-2022].* Available at: https://www.psgaz.pl/documents/21201/329214/Strategia+PSG+2016+-+2022.pdf/a95241fa-85d1-4ee6-8de7-906792e30cb4 (accessed on: 21.01.2018) (in Polish)

Polski komitet normalizacyjny (2000). *Polska norma PN-83/B-03430+A3:2000. Wentylacja w budynkach mieszkalnych, zamieszkania zbiorowego i użyteczności publicznej [Polish standard PN-83 / B-03430 + A3: 2000. Ventilation in residential buildings, collective housing and public utilities*.] Warszawa. (in Polish)

Santarsiero, A., Musmeci, L., Fuselli, S. (eds) (2015). *Workshop. La qualita dell'aria indor: acttuallesituazione national e comuntaria. L'esperienza del Gruppo di Studio Nationale sull' Inquinamento Indoor [The quality of the air indor: acttualle national situation and comuntaria. The experience of the Nationale Study Group on Indoor Pollution]*. Instituto Supriore di Sanita Roma, 28 May 2014. Ropporti ISTISAN 15/4. (in Italian)

Skowroński, P. (1997). Użytkowanie i substytucja nośników energii w mieszkalnictwie w kontekście problemu emisji gazów cieplarnianych [The use and substitution of energy carriers in housing in the context of the problem of greenhouse gas emissions]. *Biuletyn Instytutu Techniki Cieplnej Politechniki Warszawskiej [Journal of Power of Technologies]*, 85, pp.21–31. (in Polish)

Szkarowsk,i A. (2014). *Spalanie gazów. Teoria, praktyka, ekologia [Burning of gases. Theory, practice, ecology]*. Warszawa: Publishing house WNT. (in Polish)