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RISK ASSESSMENT OF THE HIGHWAY EQUIPPED WITH PROTECTIVE ENGINEERING STRUCTURES

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Abstract. *The problem of risk assessment of a highway section, which is equipped with protective engineering structures to reduce the ingredient-parametric pollution in the dwelling zone is considered, and the methodology of risk assessment «Failure Mode and Effects Analysis» (FMEA) is used to estimate the priority areas of increasing the level of safety in exploitation of the highway equipped with the protective screen.*

Key words: *highway, ingredient-parametric pollution, protective screen, risk assessment, dwelling zone, noise pollution, emergency situation, risk indexes.*

ОЦЕНКА ОПАСНОСТИ АВТОМОБИЛЬНОЙ ДОРОГИ, КОТОРАЯ ОБОРУДОВАНА ЗАЩИТНЫМИ ИНЖЕНЕРНЫМИ СООРУЖЕНИЯМИ

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Аннотация. *Рассмотрен вопрос оценки опасности участка автомобильной дороги, оборудованного защитными инженерными сооружениями для снижения ингредиентно-параметрического загрязнения селитебной зоны.*

Ключевые слова: *автомобильная дорога, ингредиентно-параметрическое загрязнение, защитный экран.*

ОЦІНКА НЕБЕЗПЕКИ АВТОМОБІЛЬНОЇ ДОРОГИ, ЩО ОБЛАДНАНА ЗАХИСНИМИ ІНЖЕНЕРНИМИ СПОРУДАМИ

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Анотація. *Розглянуто питання оцінки небезпеки ділянки автомобільної дороги, що обладнана захисними інженерними спорудами для зниження інгредієнтно-параметричного забруднення сельбищної зони.*

Ключові слова: *автомобільна дорога, інгредієнтно-параметричне забруднення, захисний екран.*

Introduction

In big cities with intensive traffic of vehicles in the stream there is an urgent need to protect the residents, who live near highways, from the harmful effect of ingredient and parametric pollution resulting from car traffic.

The overall pollution of environment which is caused by vehicles moving along the highway in general is divided into two types:

– ingredient air pollution by harmful substances which are formed as a result of the movement of vehicles;
– parametric (in particular, acoustic) pollution, which consists in emission of harmful acoustic vibrations in sound and infrasonic frequency range, and vibration.

The influence of pollutants and compounds contained in discharge gases are dangerous for people, can lead to essential changes in the functional state of a human's body and diseases.

The parametric pollution introduced as vibroacoustic vibrations influences practically all body systems and causes both short-term and long-term lasting functional changes, leading to the beginning of diseases of cardiovascular, nervous systems and weakening of immune system. The excessive noise can be the reason of nervous exhaustion, psychical depression, vegetative neurosis, peptic ulcer, disorders of endocrine and cardiovascular systems. Noise interferes with the people's work and rest, reduces the productivity of work and increases the injury rate at work and at home.

Analysis of possible ways of solving this issue showed the reasonability of using the protective screens, which have a number of advantages over other means of protection: firstly, their application is possible in urban areas that are already developed; secondly, the protective efficiency of screens is high in relation to ingredient pollution on the territories situated near highways (about 50–60 %), and in terms of acoustic waves, sound pressure levels which are reduced almost by 10–18 dB on the average and high frequency range of frequencies. It should also be noted that the combination of sound-absorbing and sound-reflecting elements enables to achieve the maximum protective effect in terms of preventing the spread of acoustic waves.

The use of protective engineering structures in the form of protective screens on the highways is the optimal solution of the issue of protecting the properties and territories, which have the higher requirements to the quality of air, but their exploitation could lead to the creation of emergency situations on highways. Driver's traffic conditions on the sector of highway equipped on both sides by the protective engineering structures can be compared with the traffic conditions in the tunnel, since they are in the condition of a certain limited space around the highway. However, they are more favourable, as there is direct contact with the outside air, which facilitates the perception of the highway and reduces the load on the driver, who may feel some discomfort in the limited space of the tunnel. In addition, there is no transition between lighting levels outside and in the tunnel, which also makes traffic conditions more favorable on this sector of highway.

At the same time, while driving on the highway equipped with screens, the driver's attention decreases, which may be an initial condition for the creation of an emergency situation not only in the given area but also at the crossroad.

Lack of information that the driver needs to handle when moving along the highway equipped with a protective screen in combination with blinking of its supports can lead the driver to fatigue, relaxation and even drowsiness [1].

Also it should be neted that the overall construction of protective screens is perceived as a massive object that can cause a driver to deviate from the trajectory of rectilinear motion and cause a car accident or complicate the traffic condition [2].

Analysis of publications

The issue of assessing the influence of engineering structures on the highway safety is considered in the works of E. Ugnenko, V. Babkov, O. Ryabushenko, etc [1, 3, 4]. It was noted that engineering structures, situated at the roadside can create an emergency situation for drivers due to the visibility limitation and change of perception of the road situation by the driver. So it is necessary to give attention to the issue of increasing the safety at these sections. The information base of decision making is formed by the results of risk assessment of the origin of on emergency situation on this section.

Aim of Research

To carry out the assessment of factors, which influence the safety of highway exploitation and to suggest the measures to increase the level of safety.

Problem Statement

To apply the methodology of risk assessment «Failure Mode and Effects Analysis» (FMEA)

for estimating the priority areas of increasing the level of safety in exploitation of highways with engineering screens.

Risk assessment of the origin of an emergency situation on a highway section with protective screens

Analysis of risk of origin of emergency situation on the highway is supposed to be carried out with the use of theory of risks and this highway has protective engineering constructions.

Risk assessment is carried out in the following order:
1) identification of dangerous factors;
2) identification of probable scenarios of elaboration of undesirable incidents;
3) risk assessment considering the frequency of probable accidents and probable accidents and probable consequences according to the defined scenarios;
4) comparison of risk indexes with the purpose to identify the priority ways of providing the safety of exploitation the sectors of highways, equipped with protective screens;
5) the development of measures to prevent the origin of emergency situation on the sector of highway, equipped with protective screen.

The results of identification of sources of danger are identified in the table 1.

Table 1 Results of identification of dangerous factors of installation the protective engineering construction along the highway

№ s/n	Description of dangerous factor	Source of origin	Reason of origin
1	Falling of protective screen or its separate elements on the roadway	Protective screen	1. Improper fixing of construction elements 2. Design defect at the stage of planning
		Weather conditions	Excessive snow or wind load
		Extraneous objects	Human's activities or other vehicles etc, which lead to destroying of construction of protective screen with the further falling on the roadway
2	Driver's limitation of visibility	Protective screen	Not taking into account the geometry of disposition of artificial construction along to the highway
3	Driver's weakening of attention	Driver's psychophysiological particularities	1. Monotony of appearance of protective screen 2. Frequency of blinking of supporting structures

The identification of dangerous factors foresees the clarification of list and reasons of origin of sources of danger, which is the basis of development the scenarios of origin and extension of emergency situation.

The analysis, which was carried out, showed, that as the source of danger of origin of emergency situation could be both the protective screen and effect of external factors (weather conditions), and driver's psychophysiological particularities. Considering these factors, below there are possible scenarios of origin and extension of emergency situation in the system «highway–motor car–protective screen»:

1) collision – can take place in the following cases:
– when a driver, trying to make the detour of obstacle, which is situated on the roadway, dramatically changes the path of motion and the vehicle gets on the other strip of way and collides with the other motor car, which moves;

– when a driver loses the attention and does not react in time at the appearance of other vehicles on the crossroad;

2) head-on crash – can take place in following cases:

– when vehicle drives runs into the element of protective screen, which may fall on the roadway for some reason;

– when driver loses control of the car and drives into protective screen, situated on the side of the road.

For the purpose of assessment of the level of influence of the reasons of further development of the scenarios mentioned above, there has been occurance of their significance, frequency of appearance, and possibility of identification to obtain the value of priority number of risk (PNR) by the method «Failure Mode and Effects Analysis» (FMEA) [5, 6]. This method concerns the group of determinate qualitative methods of analysis and risks of road accidents [4].

The assessment of significance has been carried out by the 10-point scale of seriousness of consequences. Scales of points of these criteria are identified in the table 2.

Table 2 Scale of points to the expert estimation of the reasons causing the road accident on the sector of highway equipped with the protective engineering construction

Point	Criteria of significance S	Criteria of frequency of occurrence O	Criteria of possibility identification D
10	High-risk danger	Very high (I degree)	Almost impossible
9	High-risk danger with possible prevention	Very high (II degree)	Very distant possibility
8	Very weighty influence	High (I degree)	Distant possibility
7	Weighty influence	High (II degree)	Very weak possibility
6	Moderate influence	Moderate (I degree)	Weak possibility
5	Weak influence	Moderate (II degree)	Moderate possibility
4	Very weak influence	Moderate (III degree)	Almost enough possibility
3	Insignificant influence	Low (I degree)	Enough possibility
2	Very insignificant influence	Low (II degree)	High possibility
1	Influence is absent	Minimized	The firm belief

The priority number of risk is the complex rate of danger, which is compared with the maximum permissible level of this rate. In case this number exceeds, the conclusion can be made about the necessity to apply the administrative activities towards prevention the origin of emergency situation on the sector of highway.

When the maximum level of PNR equals to 200, the conclusion can be made that six factors are significant among eight factors which are being considered.

One possible solution is the introduction of transparent modules in the structure of screen. On the one hand this causes the reducing of protection effectiveness but, on the other hand, it allows making design visually lighter and improving its perception by drivers and pedestrians [7].

Supporting structures, which are mounted by modules of protective screen when driving past them at a certain speed, can, owing to its monotony blinking, tire the driver. In this regard, it is recommended to install them at the minimum distance of 50 m from each other on straight sections of the road [1].

On curvilinear sections the spacing between them depends on the radius of the curve: with the increase of radius the distance increases between structures [1].

Color design of protective engineering construction must be done in neutral colours because the bright painting can lead to overload the driver with additional information which is irrelevant for driving.

With the aim of improving the perception it is possible to use the texture design of the screen surfaces located along the highway.

Conclusion

Proposed construction of protective engineering constructions comprehensively solves the issues of protection of dwelling zones, located near the highway, from the harmful effects of ingredient and parametric pollution.

Installation of protective screens along a particular stripe of highway can increase the danger of traffic there. Dangerous factors arise from both protective screens themselves and on the part of drivers due to the increased load on their psycho-emotional sphere.

To determine the priority directions to increase the safety of exploitation of sections of highways equipped with protective engineering constructions, the analysis of the causes of car accidents and the extent of their impact using the method «Failure Mode and Effects Analysis» has been carried out. This allowed us to determine the priority ways of application of control actions in a direct of warning the emergency situation on the highway section equipped with protective screens.

Results of rating of reasons, which cause the road accident, involving the vehicle and protective engineering constructions, obtained by the carrying out of expert estimation among the professionals in the field of road safety, are identified in the fig. 1.

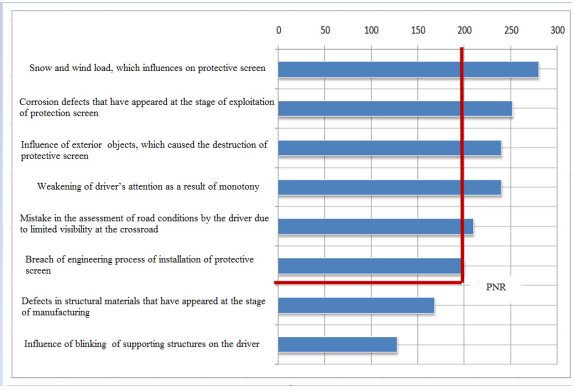

Fig. 1. The diagram of assessment of significance of observable factors

Also the psychophysiological aspects of the perception of protective screens for drivers and the ways of their improvement in the aspect of its color has been considered, adjusting the frequency of the blinking of structures and using transparent modules.

Implementation of the proposed solutions in the design of protective screen and on the stage of its installation will improve the safety of exploitation of highway sections equipped with road constructions.

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