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ЗАБЕЗПЕЧЕННЯ НАДІЙНОСТІ ЖОРСТКОГО ДОРОЖНЬОГО ОДЯГУ З ВИКОРИСТАННЯМ ВИСОКОМІЦНОГО БЕТОНУ

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ENSURING RELIABILITY OF RIGID PAVEMENT WHEN USING HIGH-STRENGTH CONCRETE

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ОБЕСПЕЧЕНИЕ НАДЕЖНОСТИ ЖЕСТКОЙ ДОРОЖНОЙ ОДЕЖДЫ С ИСПОЛЬЗОВАНИЕМ ВЫСОКОПРОЧНОГО БЕТОНА

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Problem statement.

In Ukraine about 170 thousand public roads from which only 2,4 thousand (about 1,39%) have a cement-concrete pavements. Other 98,61% of domestic highways have an asphalt concrete pavements. The operating experience of highways with an asphalt concrete pavements testifies to their essential shortcomings which main type destructions deformation of shift at the increased temperatures in the summer and a cracking during the winter period. Highways with a cement-concrete pavements have considerable advantages in comparison with asphalt concrete: high strength and durability; ensuring bigger traffic safety; availability of domestic raw materials; smaller heating at the expense of a light surface; lack of the phenomenon of rutting; a possibility of processing and reuse and even ability to provide lower noise level at the device of layers of wear.

Road bitumen as cement for asphalt concrete pavements 100% import material are, and a portlandcement for rigid pavements, is 100% produced in Ukraine. The price of guess asphalt concrete from 2001 for 2012 increased by 11,2 times. Asphalt concrete mix fine-grained dense type B, brand I by 6 – 6,5 times. Asphalt concrete mix coarse-grained porous, brand I by 5,5 – 6 times [4].

Development strategy of construction pavements is well traced at our neighbors in the West. In Germany about 65% of new roads were built with a concrete pavements. In Austria and Great Britain, the part of concrete roads is more than 50%. In Belgium cement-concrete highways is 40%, and the part of the local roads constructed on cement-concrete technology is about 60%.

Growth loading capacity and speed of cars demands continuous development of a road network, improvement constructions of pavement. The discrepancy condition of the highway to requirements of traffic flow leads to growth of number of the road accidents, reduces the speed of the movement, increases wear of cars and costs of their repair, increases fuel consumption. Use of rigid pavement with a cement-concrete on sections of roads where it is necessary can become the partial solution of this problem.

The abroad for simplification of designing of rigid pavement developed catalogs of constructions [1 – 2]. Documents of this kind were not developed in Ukraine.

Review of researches.

The theory of reliability served basis forming of probabilistic methods of calculation. Bases of the probabilistic going near the calculation of building constructions worked out M.C. Streletcky, A.P. Rzhanicin, B.B. Bolotin, A.M. Freudenthal [6 – 8].

Further development of theory reliability of building constructions had got in works of Barashikova A.Y., Beliaev B.N., Bondarovicha B.A., Budnika V.S., Gvozdeva O.O., Gemerlinga A.V., Gordeeva V.M., Goroghovaia E.V., Grabaria I.G., Dirdi V.I., Grivinga A.Y., Kazakevicha M.I., Klevcova V.A., Kostukova V.D., Koshutina B.N., Kuzdisa A.P., Luzhina O.V., Lisuka V.S., Lichova A.S., Makarova B.P., Mastachenko V.N., Mullera R.A., Murshanova V.P., Pavlova U.A., Pashinskogo V.A., Pereverzeva E.S., Pelelmutera A.V., Pichugina S.F., Podolskogo D.M., Raizera V.D., Savitskogo M.V., Segalova A.E., Skladneva M.M., Simiriagina U.V., Snarkisa B.I., Sno V.E., Soboleva D.N., Suhova U.D., Timasheva S.A, Usakovskogo S.B., Uzhpoliavichusa B., Fediakina O.I., Czapko V.K., Chipasa A.A., Chirkova V.P., Shimanovskogo V.M. and other researchers [9 – 11].

In bridge constructions there is the probabilistic-statistical approach, developed in works L.I. Ioselevskogo, V.O. Osipova, V.P. Chirkova, A.G. Barchenkova, I.Z. Aktuganova, A.I. Vasileva, C.B. Bobileva, U.P. Nechaeva and others [12].

Some aspects of providing reliability at preparation of bituminous concrete mixtures and arranging of asphalt pavements were examined in works of S.U. Rokasa [13]. In area constructions of road pavements probabilistic methods were used in works of B.S. Radovskogo, I.A. Zolotaria, V.K. Nekrasova, S.V. Konovalova, V.V. Filipova, V.M. Shestakova, U.M. Yakovleva, M.S. Koganzona and other [14 – 17].

An abroad theories of reliability building constructions were devoted works of M. Majer, A.M. Freidental, K.A. Cornella, R. Levi, A.I. Ionsona, I. Funito, A. Matie, M. Tihogo, M. Vorlicheka, and other of researchers [18 – 19].

Worked out the international standard of ISO 2394:1998* «General principles of providing reliability constructions» (ISO 2394:1998 «General principles on reliability for structures, IDT» [22].

This international standard is general basis for determination of the planning rules related to building and exploitation majority of buildings and engineering building for the wide setting, independently here the applied materials or their combinations. However, their application at the different types of build materials (concrete, steel, wood, stonework et cetera) requires the special adaptation for providing of level reliability, that would be most concerted with the requirements of normative documents on every type of building material.

At development of new norms on bridge building in Ukraine under the direction of prof. A.I. Lantuh-Liaschenko is offered estimation of reliability on the model of the Markovsky casual process with the discrete states [20].

Works from reliability of constructions road pavements unfortunately, not enough [21], to set forth the methods of their planning taking into account actual heterogeneity of loading and variation of geometrical parameters and data of physic – mechanical descriptions of soil and layers of road pavements.

Purpose and methods.

The purpose of work is improvement of a design method and increase in reliability of paving's when using high-strength concrete.

Research problems:

- establishment of settlement characteristics of high-strength concrete;
- development of a technique of assessment of reliability of road and airfield pavements from high-strength concrete;
- performance of calculations of designs of road and airfield with a pavements from high-strength concrete;
- determination of technical and economic efficiency of use of high-strength concrete in road and airfield construction.

Assessment of reliability of constructions of pavement of rigid type.

The purpose of design of roads with the set reliability is minimization of costs on construction and repair of roads taking into account the actual dispersion of parameters of a constructions of pavement.

Reliability of a constructions of pavement is defined as probability of no-failure operation at which will not be exceeded a limit state on a formula:

$$K_H = H(N(t)) = 0{,}5 + F(\beta(N(t))) = 0{,}5 + \frac{1}{\sqrt{2\pi}} \cdot \int_{\beta(N(t))}^{\infty} e^{-\frac{z^2}{2}} dz, \tag{1}$$

where $F(\beta(\beta(N(t)$ – normalized function of Laplace;

β (N(t)) – the characteristic of safety which changes during operation:

$$\beta(N(t)) = \frac{R(N(t)) - Q(N(t))}{\sqrt{S_R^2(N(t)) + S_Q^2(N(t))}}, \tag{2}$$

or

$$\beta(N(t)) = \frac{K_{мц}(N(t)) - 1}{\sqrt{V_R^2(N(t)) \cdot K_{мц}^2(N(t)) + V_Q^2(N(t))}}, \tag{3}$$

where*: R (N(t))* – average value of strength;

Q (N(t)) – average value of tension;

SR (N(t)) and *SQ (N(t))* – mean square deviations or coefficients of a variation $V_R(N(t))$ strength and $V_Q(N(t))$ tension respectively;

$K_{mts} = R/Q$ – stock coefficient.

For a case of calculations of a constructions of pavement by criteria of a limit state in any time point *of t* which answers the total intensity of the movement of N(t) vehicles: *R (N(t))* – a random variable which designates mechanical characteristics (durability on stretching at a bend *of* $R_{zg}(N(t))$ when calculating monolithic layers; the admissible tension of shift $\tau_{top}(N(t))$ – when checking durability of non-connected layers or soil of a road bed, or the general module of elasticity $E_{zag}(N(t))$ – at estimation of the general deformability of a design; *Q (N(t))* – a random variable which denotes an acting load (respectively, stretching tension at a bend *σr,* the active tension of shift $\tau_{act}(N(t))$ or the required elasticity module $E_{rubbed}(N(t))$.

For calculations for criterion of a bend of a cement-concrete plate formula of determination of tension *of* $Q(N(t)) = \sigma_{pt}$ (MPa) has an appearance:

$$\sigma_{pt} = \frac{60 \times Q_p \times K_k \times [0{,}0592 - 0{,}09284 \times ln(R_К / l_y)]}{h^2}, \tag{4}$$

where $K_k = \dfrac{K_m \times K_{умв} \times K_{шт}}{K_t}$,

Q_r – calculated loading, kN;

h – thickness of a concrete plate, m;

K_m – coefficient which considers influence of location of loading, for not reinforced pavements. K_m = 1,5; for pavements with an edge or platforms with an arrangement of strips of a rolling is not closer than 0,8 m from width of outer longitudinal edge of a paving – K_m = 1,0 for the longitudinal direction and K_m = 1,5 for cross;

$K_{умв}$ – coefficient which considers working conditions, K_{umv} = 0,66;

$K_{шт}$ – coefficient which considers influence of pin connections on conditions of contact of plates with the basis, in the availability in cross seams of pines: K_{piece} = 1,00, in the absence of pins K_{piece}= 1,05;

K_t – coefficient which considers influence of temperature warpage of plates;

Value of coefficient K_t that considers influence of temperature warpage of plates is accepted according to the table of norms [19]:

where: $l_y = \left[\dfrac{E_b \cdot (1 - \mu_o^2)}{E_o \cdot \left(1 - \mu_b^2\right)} \right]^{1/3}$ – elastic characteristic of a plate.

R_k – radius of a stamp of a wheel, m:

$$R_K = \sqrt{\frac{Q_p}{(0,1 \cdot \pi \cdot q_{ш})}}, \quad (5)$$

where q_{sh} – pressure in tires, MPa.

Durability of a concrete on stretching at a bend is determined by a formula *R (N(t))* = by *R:*

$$R = R_{лаб} \cdot K_м \cdot K_у, \quad (6)$$

where K_y – the coefficient of fatigue of concrete at repeated loading, is determined by a formula:

$$K_у = 1,08 \cdot N_p^{-0,063}, \quad (7)$$

where $K_м$ – coefficient of set of durability; for concrete of natural curing (hardening) at air temperatures over +10 °C $K_м$ = 1,2; for concrete of natural curing at air temperature below +10 °C and at winter concreting K_m = 1.

The characteristic of reliability β is established depending on the margin of safety (rigidity) on the set service life *of t*, settlement dispersion of tension (rigidity) and actual data from dispersion of parameters of properties of layers of road pavements, heterogeneity according to geometrical characteristics depending on level of quality of construction. Normative value of the characteristic of reliability for settlement levels of reliability of pavement for different categories of road are induced in [6] and it is established from conditions of a minimum of road and transport expenses on constructions service life.

Necessary thickness of layers from a concrete and a resource constructions of pavement by quantity of cycles of applying of settlement loading throughout all service life for ensuring the set level of reliability is specified in table 1.

Table 1 – The recommended thickness of cement-concrete layers

Category of the road	Thickness of a concrete, cm	Intensity of the movement	
		Average daily	Total quantity of settlement axes, one. / in a service life
1	2	3	4
I-a	26-32	it is more than 1500	10 000 000 – 32 000 000
I-b – II	24-26	1250 – 1500	2 000 000 – 10 000 000
III	22-24	500 – 1250	500 000 – 2 000 000
IV	18-22	250 – 500	150 000 – 500 000

When calculating strengthening of pavement, it is recommended to use experimentally obtained data on determination of average value and a variation of the general module of elasticity of a constructions of pavement during the settlement period.

For calculation of reliability it is necessary to define heterogeneity of a constructions for different groups of a limit state. At the same time perhaps experimental definition of heterogeneity of durability V_R for different technological operations and experimental or theoretical definition of a variation of tension V_Q way of tool inspection or when calculating behind the technique given below.

Calculations of heterogeneity of tension and durability of a design of rigid road pavements.

Definition of heterogeneity by different criteria of a limit state is established by calculation methods of mathematical statistics.

For definition of influence of dispersion of parameters_(modules of elasticity *of* E_1 *and* E_2, thickness of layers *h,* intensity of loading *p* and diameter of a print of a wheel *D*) on dispersion of the general module of elasticity of pavement V_{Ezag}, [5] and tension of stretching at a bend V_σ [6] it is used approximate formulas which are based on decisions of the theory of elasticity.

Calculations of heterogeneity of tension of stretching at a bend.

The formula for definition of the general heterogeneity of tension of stretching at a bend has an appearance:

$$V_\sigma = \left[\begin{array}{l} \left(\frac{\partial\sigma}{\partial Q_k}\right)^2 \left(\frac{\bar{Q}_k}{\bar{\sigma}}\right)^2 V_{Qk}{}^2 + \left(\frac{\partial\sigma}{\partial E_b}\right)^2 \left(\frac{\bar{E}_b}{\bar{\sigma}}\right)^2 V_{E_b}{}^2 + \left(\frac{\partial\sigma}{\partial E_{осн}}\right)^2 \left(\frac{\bar{E}_{осн}}{\bar{\sigma}}\right)^2 V_{E_{осн}}{}^2 + \\ + \left(\frac{\partial\sigma}{\partial h}\right)^2 \left(\frac{\bar{h}}{\bar{\sigma}}\right)^2 V_h{}^2 + \left(\frac{\partial\sigma}{\partial D}\right)^2 \left(\frac{\bar{D}}{\bar{\sigma}}\right)^2 V_D{}^2 \end{array} \right]^{1/2}, \qquad (8)$$

where $\bar{\sigma}$ – average value of tension to stretching at a bend, N/mm^2;
$\bar{Q}_k$ – average value of the current load of a wheel, kN;
V_{Qk} – loading variation coefficient;
$\bar{E}_b$ – average value of the module of elasticity of a concrete, N/mm^2;
V_{E_b} – coefficient of a variation of the module of elasticity of a concrete;
$\bar{E}_{осн}$ – average value of the basis equivalent module of elasticity of the basis, N/mm^2;
$V_{E_{осн}}$ – coefficient of a variation of the equivalent module of elasticity of the basis;
$\bar{h}$ - average value of thickness of a cement-concrete plate, m;
C_h - plate thickness variation coefficient;
$\bar{D}$ - average value of diameter of a print of a wheel, m;
V_D – coefficient of a variation of diameter of a print of a wheel.

For a possibility of calculations for a formula (8) it is necessary to execute differentiation of a formula (4) and to establish average values and coefficients of a variation of all initial parameters.

Partial derivatives in a formula (8) are determined by formulas:

$$\frac{\partial\sigma_{pt}}{\partial Q_k} = 60 \cdot \frac{K_k}{h^2} \cdot ((5,92 \cdot 10^{-2} - 9,284 \cdot 10^{-2} \times ln(\sqrt{\frac{6 \cdot (R_k)}{h^2 \cdot l_y}})) - 0,04642, \qquad (9)$$

$$\frac{\partial\sigma_{pt}}{\partial E_b} = \frac{1,8568 \cdot Q_p \cdot K_k}{h^2 \cdot E_b}, \qquad (10)$$

$$\frac{\partial\sigma_{pt}}{\partial E_{осн}} = -\frac{1,8568 \cdot Q_p \cdot K_k}{h^2 \cdot E_{осн}}, \qquad (11)$$

$$\frac{\partial\sigma_{pt}}{\partial h} = \frac{120 \cdot Q_p \cdot K_k \cdot [0,0592 - 0,09284 \cdot ln\left(\frac{R_k}{l_y}\right)^2]}{h^2} + 5,5704 \cdot Q_k \cdot \frac{K_k}{h^2}, \qquad (12)$$

$$\frac{\partial\sigma_{pt}}{\partial D} = \frac{33,4224 \cdot Q_p \cdot K_k}{h^2 \cdot D}. \qquad (13)$$

General heterogeneity of multilayered thickness of a construction:

$$V_{h\Sigma} = \frac{1}{h_\Sigma}\sqrt{\sum_{i=1}^{n}(V_{h_i}\cdot h_i)^2}, \tag{14}$$

where: h_Σ – total thickness of road pavement, m;

h_i – thickness i of layer, m;

n – quantity of layers in construction or quantity of layers pavement for criterion of a bend of monolithic layers;

V_{hi} – the coefficient of a variation of thickness of a layer of pavement, is determined experimentally, or, in the absence of data, by a formula:

$$V_{h_i} = \frac{A_h}{B_h + h_i}, \tag{15}$$

where parameters A_h = 2,84; B_h = 10,2 for asphalt concrete and A_h=*2,84 and* B_h= 5,6 for other materials processed by organic cement.

For a cement-concrete plate:

$$V_h = 0,200\cdot(h)^{-0,31}, \tag{16}$$

where h – thickness of a cement-concrete plate;

For basis layers:

$$V_{hосн} = \frac{66,395}{100}\cdot h_{осн}^{-0,588}, \tag{17}$$

where h_{osn} – thickness of a layer of the basis of rigid pavement.

Coefficient of a variation of the module of elasticity of layers of the basis of multilayered pavement:

$$V_{E\Sigma} = \frac{1}{E_{cp}\cdot h_\Sigma}\cdot\sqrt{\sum_{i=1}^{n}(E_i\cdot h_i)^2\cdot(V_{Ei}+V_{hi})^2}, \tag{18}$$

where: V_{ei} – coefficient of a variation of the module of elasticity of a layer pavement.

$V_{Ei} = A_E\cdot E_i^{B_E}$, here parameters A_E= 0,9056, B_E=-0,265;

E_i – the elasticity module i a layer, MPa;

E_{sr} – average module of elasticity of a package of layers, MPa.

Coefficient of a variation of parameters of loading.

The coefficient of a variation of diameter of a print of a wheel is accepted according to table 2 for roads of the I-IV category [4].

Table 2 – Coefficient of a variation of parameters

Category of the road	Durability variation coefficient V_R (rigidity) for rigid pavement		Tension variation coefficient, V_σ for criteria of calculations	
	for stretching at a bend, V_R	for shift, V_C	bend of monolithic layers, V_σ	Shift in incoherent layers, V_τ
1	2	3	4	5
Ia	0,10	0,14	0,15	0,12
Ib – II	0,12	0,16	0,17	0,12
III	0,12	0,18	0,20	0,14
IV	0,15	0,20	0,22	0,16

Note. The coefficient of a variation of diameter of a print of a wheel is accepted equal V_D= 0,05 for roads of all categories. The coefficient of a variation of pressure changes from 0,15 for roads of the I-III to

0,25 roads of the IV category. The coefficient of a variation of load of a wheel is equal 0,125 for roads of I, 0,15 – II, 0,175 – the III categories and 0,25 for the IV category.

Determination of coefficient of a variation of durability of a concrete on stretching at a bend.

The coefficient of a variation of durability of a concrete on stretching at a bend is determined by a formula

$$V_R=\left[\left(\frac{\partial R}{\partial R_{клаб}}\right)^2\left(\frac{\overline{R}лаб}{\overline{R}}\right)^2 V_{Raбб}{}^2+\left(\frac{\partial R}{\partial K_м}\right)^2\left(\frac{\overline{K}v}{\overline{R}}\right)^2 V_{Kмv}{}^2+\left(\frac{\partial R}{\partial N_p}\right)^2\left(\frac{\overline{N}p}{\overline{R}}\right)^2 V_{Np}{}^2\right]^{1/2}, \quad (19)$$

where value of partial derivatives is equal:

$$\frac{\partial R}{\partial R_{лаб}}=1,08\cdot\frac{K_{nm}}{N_{pt}^{6,3\cdot10^{-2}}}, \quad (20)$$

$$\frac{\partial R}{\partial K_{nm}}=1,08\cdot\frac{R_{lab}}{N_{pt}^{6,3\cdot10^{-2}}}, \quad (21)$$

$$\frac{\partial R}{\partial N_{pt}}=-6,804\cdot10^{-2}\cdot R_{lab}\cdot\frac{K_{nm}}{N_{pt}^{1,063}}. \quad (22)$$

Coefficient of a variation of laboratory durability of concrete on stretching at a bend:

-at construction with reached by level of quality

$$V_{Rlab} = -0,0451\cdot B_{btb} + 0,2653, \quad (23)$$

-at excellent quality

$$V_{Rlab} = -0,0321\cdot B_{btb} + 0,1884, \quad (24)$$

where B_{btb} – a class of durability of a concrete on stretching at a bend.

The coefficient of a variation of the module of elasticity of a concrete is determined by a formula:

$$V_{Eb}=-2,6630150\cdot10^{-10}\cdot E_b^2+8,5802939\cdot10^{-6}\times E_b+0,12777443, \quad (25)$$

where E-$_b$ module of elasticity of a concrete, MPa.

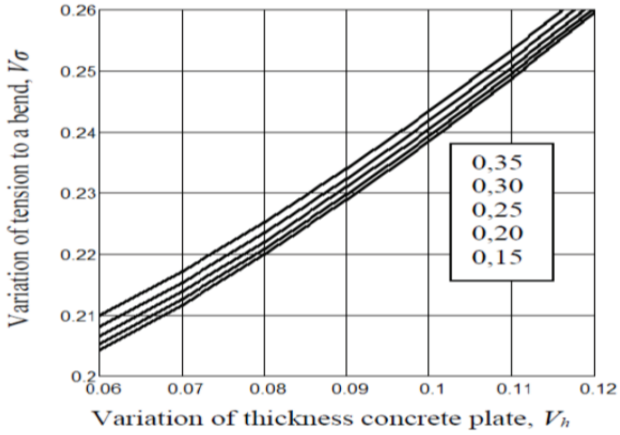
The coefficient of a variation of the module of elasticity of soil of a road base is determined by a formula:

$$V_{Egrlab} = 0,0565 + 0,065\cdot ln\,(E)_{gr}, \quad (26)$$

where E_{gr} – module of elasticity of soil of a road base.

Results and Discussion.

The example of the analysis of the theoretical solution of tasks with use of formulas 1 – 26 about influence of factors of heterogeneity of tension and durability rigid pavement is given in fig. 1 – 3.



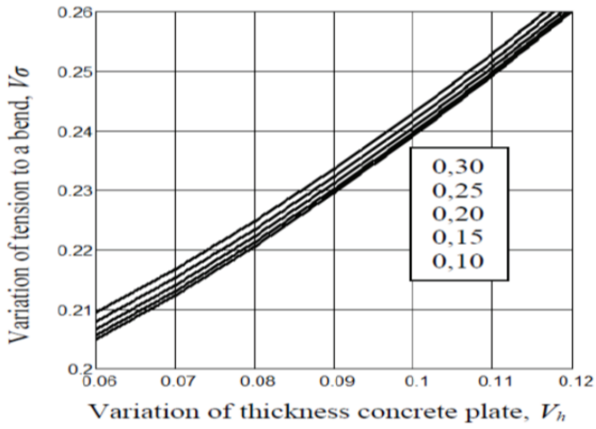


Figure 1 – Change of coefficient of a variation of tension to stretching at a bend from a change of:
a) coefficient of a variation of the module of elasticity of the basis 0,10; 0,15; 0,20; 0,25; 0,30;
b) coefficient of a variation of the module of elasticity of a concrete 0,10; 0,15; 0,20; 0,25; 0,30

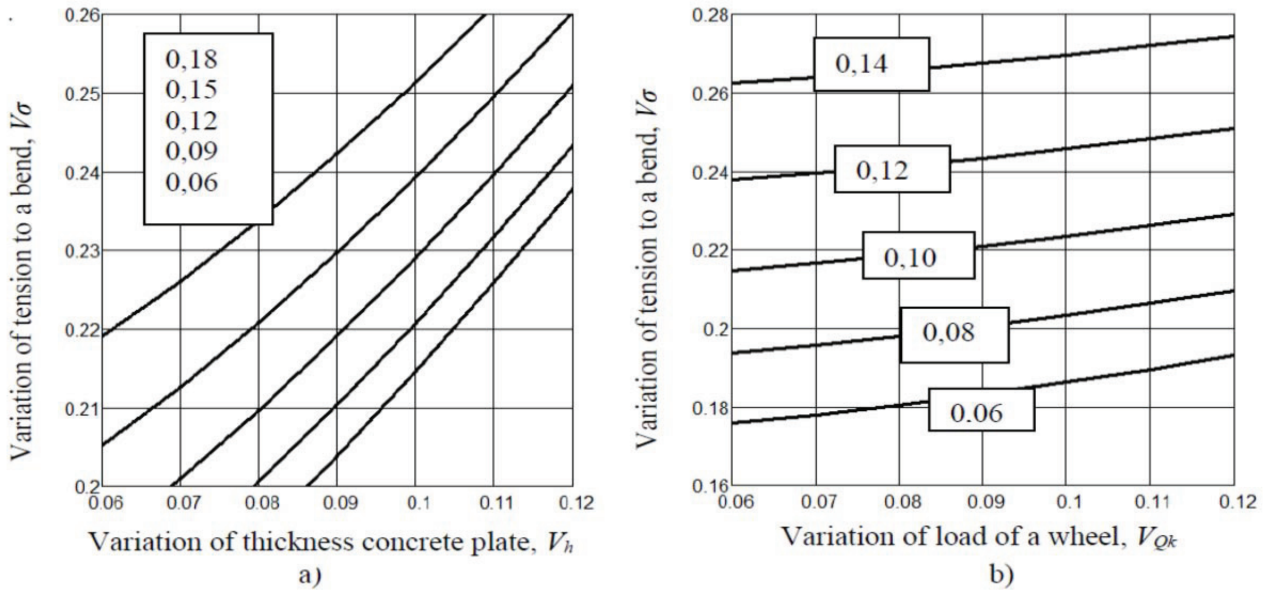


Figure 2 – Change of coefficient of a variation of tension to stretching at a bend from a variation of: a) thickness of a cement-concrete plate at change of coefficient of a variation of load of a wheel 0,06; 0,09; 0,12; 0,15; 0,18; b) and coefficient of a variation of thickness of a cement-concrete plate 0,06; 0,08; 0,10; 0,12; 0,14

Durability variation coefficient to stretching at a bend is also crucial for ensuring reliability of a design therefore strict control of quality at production of concrete mixes on cement plants and the device of cement-concrete pavements is required.

When calculating rigid pavement for determination of coefficient of a variation of tension to stretching at bend C_σ can to use the nomogram (Fig. 3) or table 3.

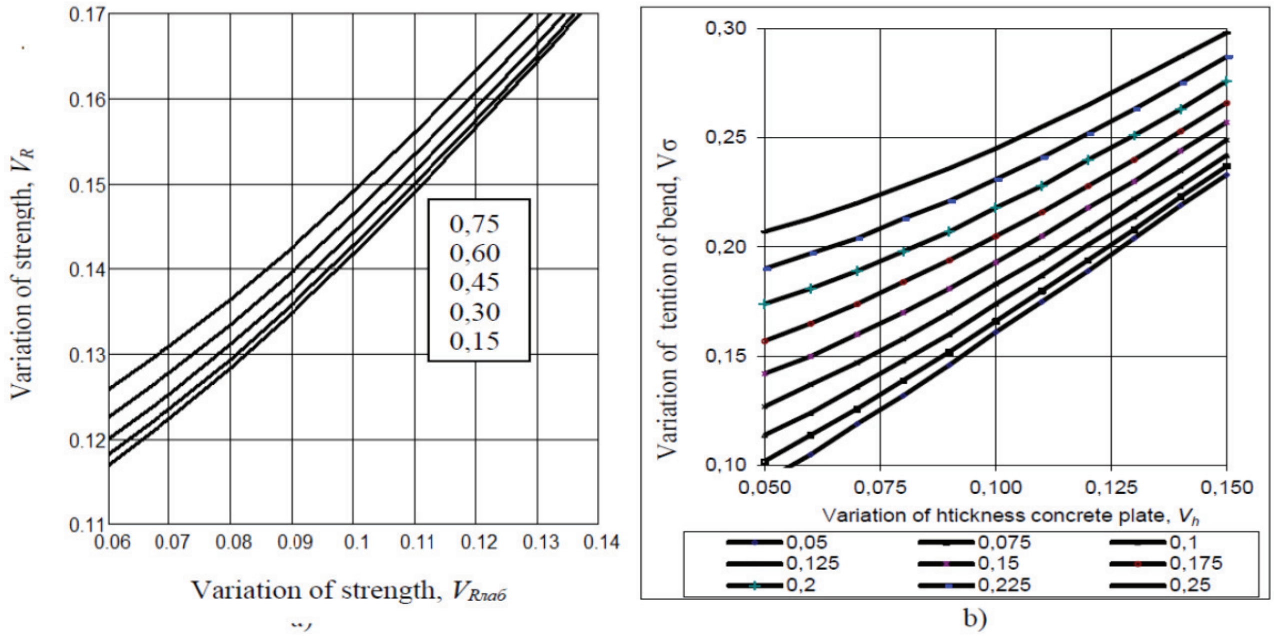


Figure 3 – Change of coefficient of a variation of durability to stretching at a bend from a variation of laboratory durability at change of coefficient of a variation of intensity of the movement respectively 0,15; 0,30; 0,45; 0,60; 0,75; b) the monogram for calculation of coefficient of a variation of tension to stretching at a bend V_σ depending on coefficient plate thickness variations V_h at the known variation of loading V_{Qk}

The analysis of fig. 3 specifies that thickness and increase in a variation of thickness have the greatest influence on change of coefficient of a variation of tension to stretching at a bend.

Table 3 – Calculated values of coefficient of a variation of tension to stretching at a bend V_σ depending on coefficient variations of thickness of a cement-concrete plate V_h at the known variation of loading V_{Ok}

Thickness variation coefficient V_h,	The coefficient of a variation of tension *of* V_σ, at a loading variation V_{Qk}								
	0,05	0,075	0,10	0,125	0,15	0,175	0,20	0,225	0,25
0,05	0,09	0,10	0,11	0,13	0,14	0,16	0,17	0,19	0,21
0,06	0,11	0,11	0,12	0,14	0,15	0,17	0,18	0,20	0,21
0,07	0,12	0,13	0,14	0,15	0,16	0,17	0,19	0,20	0,22
0,08	0,13	0,14	0,15	0,16	0,17	0,18	0,20	0,21	0,23
0,09	0,15	0,15	0,16	0,17	0,18	0,19	0,21	0,22	0,24
0,10	0,16	0,17	0,17	0,18	0,19	0,21	0,22	0,23	0,25
0,11	0,18	0,18	0,19	0,20	0,21	0,22	0,23	0,24	0,26
0,12	0,19	0,19	0,20	0,21	0,22	0,23	0,24	0,25	0,27
0,13	0,20	0,21	0,21	0,22	0,23	0,24	0,25	0,26	0,28
0,14	0,22	0,22	0,23	0,24	0,24	0,25	0,26	0,28	0,29
0,15	0,23	0,24	0,24	0,25	0,26	0,27	0,28	0,29	0,30

Note. At intermediate values of input parameters, the coefficient of a variation is defined by interpolation.

Conclusions.

The pavements from high-strength concrete has advantages over the existing types of pavements in that what the roads from a concrete have sufficient roughness of a surface which allows to develop a significant speed of movement of cars, the biggest durability, small wear of a surface and coefficient of resistance of the movement at cement-concrete pavements smaller than at pavements of other types whereby the reduces fuel consumption and tire wear.

On the basis of the conducted researches are established settlement characteristics of high-strength concrete; the technique of assessment of reliability of road and airfield pavements from high-strength concrete is developed, the analysis of influence of factors on reliability of designs of road and airfield with a pavements from high-strength concrete is made; it is defined technical and economic efficiency of use of high-strength concrete in road and airfield construction.

It is established that tension variation coefficient to stretching at a bend almost linearly increases at change of a variation of thickness of a cement-concrete plate and little depends as on coefficient of a variation of the module of elasticity of the basis, and the module of elasticity of a concrete at their change in range from 0,10 to 0,30.

The analysis of results of calculations specifies that thickness and increase a variation of thickness have the greatest influence on change of coefficient of a variation of tension to stretching at a bend and respectively on reliability of rigid pavements.

Durability variation coefficient to stretching at a bend is also crucial for ensuring reliability of a constructions of pavement therefore strict control of quality at production of concrete mixes on cement plants and the device of cement-concrete pavements is required.

At capital repairs and reconstruction, the existing pavements need to be considered as the basis for strengthening cement-concrete. At new construction it is necessary to give preference to pavements from high-strength concrete (B 40 … B 60 and above).

Comparison of cost of binders for construction the cement-concrete and asphalt concrete pavements indicates on relation of prices bitumen/cement from 5,9 to 6,1 times, the relation asphalt concrete mix / cement-concrete mix is 2,1 … 2.8 times, the average is 2.5 times.

Comparison of cost of materials and expenses throughout life cycle of rigid and not rigid pavements indicates the need constructions roads in Ukraine with a cement-concrete pavement.

It is necessary to develop the catalog of rational construction of rigid pavement for simplification of construction of rigid pavements.

By results of researches are developed methodical recommendations for application for the purpose of ensuring reliability of designs of rigid pavement when using a high-strength concrete.

REFERENCES

1. Sheynin A.M. (1991) Tsementobeton dlya dorozhnykh i aerodromnykh pokrytiy[Cement concrete for road and airfield pavements]. Moscow: Transport, 151 pp. [in Russian].

2. Katalog typowych konstrukcji nawierzchni sztywnych (2001) [Catalog of typical rigid pavement constructions]. Warszawa, Instytut Badawczy Drog i Mostow, 91 pp. [in Polish].

3. Rekomendaciji po standartyzaciji vlashtuvannja verkhnikh shariv dorozhnjogho odjaghu ob'jektiv transportnogho budivnyctva (2001) [Recommendations for standardization of the arrangement upper layers of road clothes of transport construction objects]. (RSVDO 01) Dresden: 71 pp. [in Ukrainian].

4. Gameliak I.P. (2012) Pro efektyvnistj vykorystannja vysokomicnogho cementobetonu dlja budivnyctva zhorstkykh pokryttiv [The effectiveness of use high-strength cement-concrete construction for rigit pavements]. Kiev, Car roads and road construction № 85,. p. 45 – 54 [in Ukrainian].

5. Gameliak I. P., Koreckyj A. S., Koreckyj S. S. (2013) Pro neobkhidnistj budivnyctva v Ukrajini avtomobiljnykh dorigh iz cementobetonnym pokryttjam [On the necessity of building in Ukraine roads with cement-concrete coating]. Roadster of Ukraine №5, Scientific and Technical Collection, p. 24 – 31 [in Ukrainian].

6. Bolotin V.V. (1982) Metody teorii veroyatnostey i teorii nadezhnosti v raschetakh sooruzheniy [Methods of probability theory and reliability theory in the calculations of structures] Moscow: 2nd ed., Stroyizdat, 351 pp [in Russian].

7. Rzhanitsyn A.R. (1967) Razvitie v SSSR veroyatnostnykh metodov rascheta sooruzheniy [Development in the USSR of probabilistic methods for calculating structures] Moscow: Construction mechanics and structure calculation № 4, Stroyizdat [in Russian].

8. Rzhanitsyn A.R. (1978) Teoriya rascheta stroitelnykh konstruktsiy na nadezhnost [Theory of calculation of building structures for reliability] Moscow: Stroyizdat,. 239 pp. [in Russian].

9. Rayzer, V.D. (2010) Teoriya nadezhnosti sooruzheniy [The theory of reliability of structures]. Moscow: Scientific publication, Publishing house DIA, 384 pp. [in Russian].

10. Kudzis A.P. (1985) Otsenka nadezhnosti zhelezobetonnykh konstruktsiy [Evaluation of the reliability of reinforced concrete structures]. Vilnius: Toklas, 155 pp. [in Russian].

11. Driving A.Ya. (1972) Rekomendatsii po primeneniyu ekonomiko-statisticheskikh metodov pri raschetakh sooruzheniy s chisto ekonomicheskoy otvetstvennostyu [Recommendations on the application of economic and statistical methods in the calculation of structures with a purely economic responsibility]. TsNIISK [in Russian].

12. Chirkov V.P. (1980) Veroyatnostnye metody rascheta mostovykh zhelezobetonnykh konstruktsiy [Probabilistic methods for calculating bridge concrete structures]. Moscow: Transport, 134 pp. [in Russian].

13. Rokas S.Yu. (1977) Statisticheskiy kontrol kachestva v dorozhnom stroitelstve [Statistical quality control in road construction]. Moscow: Transport, 152 pp. [in Russian].

14. Zolotar I.A., Nekrasov V.K., Konovalov S.V., Yakovlev Yu.M., Koganzon M.S. (1977) Povyshenie nadezhnosti avtomobilnikh dorog [Improving the reliability of roads]. Moscow: Pod red. I.A.Zolotarya, Transport, 183 pp. [in Russian].

15. Koganzon M.S., Yakovlev Yu.M. (1981) Kachestvo i nadezhnost dorozhnogo stroitelstva. Uchebnoe posobie [Quality and reliability of road construction. Tutorial]. Moscow: MADI, 89 pp. [in Russian].

16. Semenov V.A., Aksenov B.G., Kozlov S.P. (1979) Raschet odnorodnosti dorozhnykh odezhd [Calculation of road uniformity]. Moscow: Construction and maintenance of roads, 45-52 p. [in Russian].

17. Zolotar I.A. (1977) Metodika kolichestvennoy otsenki nadezhnosti avtomobilnykh dorog po prochnosti dorozhnykh odezhd [Methods of quantitative assessment of the reliability of roads for durability of road pavements]. Moscow: Actual problems of road pavement mechanics, Transport, 183 pp. [in Russian].

18. Augusti G., Baratta A., Kashiati F. (1988) Veroyatnostnye metody v stroitelnom proektirovanii [Probabilistic methods in building design]. Moscow: trans. from eng. V.D.Sukhova. Stroyizdat, 584 pp. [in Russian].

19. Kapur K., Lamberson L. (1980) Nadezhnost i proektirovanie sistem [Reliability and system design]. Moscow: trans from eng. Ye.G. Kovalenko, ed. I.A.Ushakova. Mir, 604 pp. [in Russian].

20. Lantukh-Ljashhenko A.I. (1999) Ocinka nadijnosti sporudy za modellju markovsjkogho vypadkovogho procesu z dyskretnymy stanamy [Estimation of the reliability of the construction on the model of a random Markov process with discrete states]. Kiev: digest Roads and road construction № 57, UTU, 183-188 pp. [in Ukrainian].

21. ISO 2394: 2015. General principles on reliability for structures [Zagalni principi nadijnosti konstrukcij]. Principes généraux de la fiabilité des constructions. STANDARD. ISO. 2394. [In English].

22. Gameliak I.P. (2005) Osnovy zabezpechennja nadijnosti konstrukcij dorozhnjogho odjaghu: Avtoreferat dysertaciji na zdobuttja vchenogho stupenja d-ra tekhn. nauk: 05.22.11 [The basis of ensuring the reliability of construction of road clothes: The author's abstract of the dissertation on obtaining a scientific degree of D.Sc., 05.22.11]. Kiev: NTU, 33 pp. [in Ukrainian].

23. MRV.2.3 37641918-885:2017 Metodychni rekomendaciji shhodo zabezpechennja nadijnosti konstrukcij zhorstkykh dorozhnikh odjaghiv avtomobiljnykh dorigh pry vykorystanni vysokomicnogho cementobetonu (2018) [Methodical recommendations for ensuring the reliability of constructions of rigid road clothes of highways with the use of high-strength concrete cement] Kiev: Ukravtodor, 69 pp. [in Ukrainian].

РЕФЕРАТ

Гамеляк І.П. Забезпечення надійності жорсткого дорожнього одягу з використанням високоміцного бетону / І.П. Гамеляк, М.М. Дмитрієв, А.М. Дмитриченко // Вісник Національного транспортного університету. Серія «Технічні науки». Науково-технічний збірник. – К. : НТУ, 2019. – Вип. 1 (43).

Наведена методика забезпечення надійності конструкцій жорстких дорожніх одягів автомобільних доріг при використанні високоміцного цементобетонну. Методика розроблена на основі узагальнення досвіду експлуатації конструкцій жорстких дорожніх одягів автомобільних доріг при використанні високоміцного цементобетонну, аналізу проведених експериментальних досліджень та містить вимоги, необхідні при проектуванні, конструюванні та розрахунку конструкцій жорстких дорожніх одягів автомобільних доріг при використанні високоміцного цементобетонну, зокрема вимоги до будівельних матеріалів, що застосовуються. Порівняння вартості матеріалів та витрат протягом життєвого циклу жорстких та не жорстких покриттів вказує на необхідність будівництва в Україні доріг з цементобетонним покриттям.

Встановлено, що коефіцієнт варіації напруги розтягування при вигині практично лінійно зростає при зміні варіації товщини цементобетонної плити і мало залежить як від коефіцієнта варіації модуля пружності підстави, так і модуля пружності цементобетону при їх зміні в діапазоні від 0,10 до 0,30.

Аналіз результатів розрахунків показує, що товщина і збільшення варіація товщини мають найбільший вплив на зміну коефіцієнта варіації напруги розтягування при вигині і відповідно на надійність жорсткого дорожнього одягу.

Коефіцієнт варіації міцності розтягування при вигині також має вирішальне значення для забезпечення надійності конструкції дорожнього одягу, тому потрібно жорсткий контроль якості при виготовленні бетонних сумішей на ЦБЗ і пристрої цементобетонних покриттів.

При капітальному ремонті та реконструкції існуючих покриття потрібно розглядати як підставу для посилення цементобетоном. При новому будівництві необхідно віддавати перевагу покриттям з високоміцного бетону (В 40 ... В 60 і вище).

Для полегшення проектування жорстких дорожніх одягів необхідно розробити каталог раціональних конструкцій жорстких дорожніх одягів.

За результатами досліджень розроблено методичні рекомендації призначені для застосування з метою забезпечення надійності конструкцій жорстких дорожніх одягів автомобільних доріг загального користування при використанні високоміцного цементобетону.

КЛЮЧОВІ СЛОВА: ВИСОКОМІЦНИЙ ЦЕМЕНТОБЕТОН, ЦЕМЕНТОБЕТОН, ДОРОЖНІЙ ОДЯГ, НАДІЙНІСТЬ, РОЗРАХУНОК НАДІЙНОСТІ.

ABSTRACT

Gameliak I.P., Dmitriev M.M., Dmytrychenko A.M. Ensuring reliability of rigid pavement when using high-strength concrete. Visnyk National Transport University. Series «Technical sciences». Scientific and Technical Collection. – Kyiv: National Transport University, 2019. – Issue 1 (43).

The method of ensuring the reliability constructions of rigid road clothing with the use of high-strength cement-concrete. The methodology is based on the generalization experience of operating high-strength road-building road vehicles with the use of high-strength cement concrete, the analysis of experimental research carried out, and contains requirements for the design, construction and calculation constructions of rigid road clothing using high-strength cement concrete, in particular requirements for

building materials, applied. Comparison of the cost of materials and costs during the life cycle of hard and hard coatings indicates the need to build roads in Ukraine with cement-concrete coating.

It is established that the coefficient of variation of tensile stress at bending practically linearly increases with change in the thickness variation of a cement concrete slab and depends little on both the coefficient of variation af the modulus elasticity of base and the modulus of elasticity cement concrete with their change in the range from 0.10 to 0.30.

Analysis of the calculations results shows that the thickness and increase of the thickness variation have the greatest influence on the change in the coefficient of variation of stretching voltage at bending and, accordingly, the reliability of hard road clothing.

The coefficient of variation of stretching strength at bending is also crucial for ensuring the reliability of the design road clothing, therefore, strict quality control is required in the manufacture of concrete mixtures in the plant and cement-concrete coatings.

When major repairs and reconstruction existing coatings should be considered as a basis for strengthening cement concrete. In the new construction it is necessary to give preference to the coating of high-strength concrete (B 40 ... 60 and above).

To facilitate the design rigid road clothing, it is necessary to develop a catalog of rational designs rigid road clothing.

According to the results of the research, the methodical recommendations have been developed for use in order to ensure the reliability of the structures rigid road clothing for general roads using high-strength cement concrete.

KEY WORDS: HIGH-STRENGTH CEMENT-CONCRETE, CEMENT-CONCRETE, PAVEMENT, RELIABILITY, RELIABILITY CALCULATION.

РЕФЕРАТ

Гамеляк И.П. Обеспечение надежности жесткого дорожной одежды с использованием высокопрочного бетона / И.П. Гамеляк, Н.Н. Дмитриев, А.Н. Дмитриченко // Вестник Национального транспортного университета. Серия «Технические науки». Научно-технический сборник. – К.: НТУ, 2019. – Вып. 1 (43).

Наведена методика обеспечения надежности конструкций жестких дорожных одежд автомобильных дорог при использовании высокопрочного бетона. Методика разработана на основе обобщения опыта эксплуатации конструкций жестких дорожных одежд автомобильных дорог при использовании высокопрочного бетона, анализа проведенных экспериментальных исследований и содержит требования, необходимые при проектировании, конструировании и расчете конструкций жестких дорожных одежд автомобильных дорог при использовании высокопрочного бетона, включая требования к строительным материалам, которые применяются. Сравнение стоимости материалов и расходов в течение жизненного цикла жестких, и не жестких покрытий указывает на необходимость строительства в Украине дорог с цементобетонным покрытием.

Установлено, что коэффициент вариации напряжения растяжения при изгибе практически линейно возрастает при изменении вариации толщины цементобетонной плиты и мало зависит как от коэффициента вариации модуля упругости основания, так и модуля упругости цементобетона при их изменении в диапазоне от 0,10 до 0,30.

Анализ результатов расчетов показывает, что толщина и увеличение вариация толщины имеют наибольшее влияние на изменение коэффициента вариации напряжения растяжения при изгибе и соответственно на надежность жесткой дорожной одежды.

Коэффициент вариации прочности растяжение при изгибе также имеет решающее значение для обеспечения надежности конструкции дорожной одежды, поэтому необходим жесткий контроль качества при изготовлении бетонных смесей на ЦБЗ и устройства цементобетонных покрытий.

При капитальном ремонте и реконструкции существующих покрытий следует рассматривать как основу для усиления цементобетоном. При новом строительстве необходимо отдавать предпочтение покрытием из высокопрочного бетона (В 40 ... В 60 и выше).

Для облегчения проектирования жестких дорожных одежд необходимо разработать каталог рациональных конструкций жестких дорожных одежд.

По результатам исследований разработаны методические рекомендации предназначены для применения с целью обеспечения надежности конструкций жестких дорожных одежд автомобильных дорог общего пользования при использовании высокопрочного цементобетона.

КЛЮЧЕВЫЕ СЛОВА: ВЫСОКОПРОЧНЫЙ ЦЕМЕНТОБЕТОН, ЦЕМЕНТОБЕТОН, ДОРОЖНАЯ ОДЕЖДА, НАДЕЖНОСТЬ, РАСЧЕТ НАДЕЖНОСТИ.

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