ISSN 1846-6168 (Print), ISSN 1848-5588 (Online)
https://doi.org/10.31803/tg-20190518181647

Preliminary communication

THE USE OF CEMENT CONCRETE PAVEMENTS FOR ROADS, DEPENDING ON CLIMATIC CONDITIONS

Iryna SOLONENKO

Abstract: The development of road network infrastructure is an important component of the economic development of the European Union. Updating of the road network contributes to the integration of the economies of countries into a coherent whole. The road network provides the free movement of citizens, the movement of goods and the effective implementation of various services. The increase in the length of the road network leads to an increase in the financial and material costs necessary to ensure its maintenance and repair. One of the ways to reduce costs is by strengthening the physic-mechanical and operational characteristics of the pavement due to the widespread use of cement concrete. The quality of the pavement of cement concrete depends largely on the rational selection of its composition. This allows a significant increase in the durability of road pavement. The purpose of the research was: the development of recommendations for the rational selection of the composition of the road pavement material of cement concrete, aimed at upgrading longevity, and taking into account its frost resistance grade. According to the goal, the following tasks were developed: the analyses of the climatic zones in which the road network of the European Union is located; the development of a research plan, a selection of the response function and influence factors; the study of physico-mechanical and operational characteristics of the researched material of road pavement; on the basis of the obtained data, the calculation of the complex of experimental-statistical models, which describe the physico-mechanical and operational characteristics of the road pavement material; on the basis of experimental statistical models, a method was proposed for selecting the rational compositions of the cement concrete pavement road material depending on the conditions of its application. The results presented in the article can be used in engineering and scientific practice for the selection of road pavement from cement concrete for highways.

Keywords: cement concrete; experimental statistical models; highway; road pavement; transport corridor; weather conditions

1 INTRODUCTION

The network of European roads has a considerable length. They ensure the stable development of the European Union (EU) countries. European roads are combined in a number of transport corridors. The main direction of traffic in these corridors: from north to south and from west to east. They enable the free movement of citizens and various goods and the performance of necessary services [1]. EU roads are directly adjacent to the road network of Belarus, Ukraine, Moldova and Russia. The distinctiveness of the roads of Ukraine and Moldova is the low quality of the road pavement, which is caused by the insufficient allocation of funds for their maintenance and repair.

As the analysis of the works [2, 3] shows, the condition of the roads mainly depends on the condition of the road pavement. The defects of road pavement (Fig. 1) significantly complicate the effective operation of vehicles, they reduce their speed and endanger traffic safety.

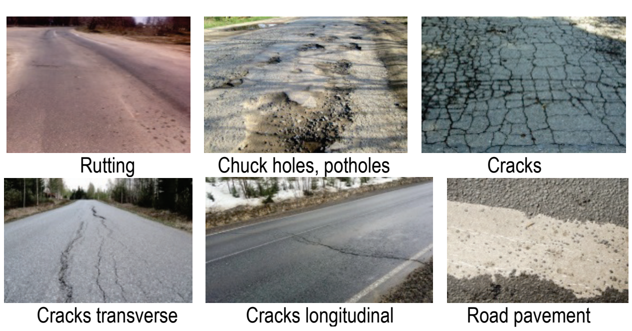

Figure 1 Defects of road pavement

The large length of EU roads (Tab. 1) requires significant funds for their maintenance and repair [4].

Table 1 The length of main roads, highways and specific sections of roads in the EU countries [4]

No.	Country	Main-line highway	Hard road pavement	Ground road pavement	General
1	Austria	2 223	200 000	0	202223
2	Belgium	1 763	120 514	33 498	155775
3	Bulgaria	801	43 649	440	44890
4	Great Britain	3 557	344 000	54 350	401907
5	Hungary	1 481	76 075	123 492	201048
6	Germany	12 917	644 480	0	657397
7	Greece	2 311	107 406	9 594	119311
8	Denmark	1 205	74 558	0	75763
9	Ireland	1 224	91 145	5 457	97826
10	Spain	16 583	683 175	0	699758
11	Italy	6 758	487 700	0	485458
12	Cyprus	254	8 564	4 442	13260
13	Latvia	0	14 707	57 737	72444
14	Lithuania	0	13 584	8 242	21 826
15	Luxembourg	152	2 899	0	3051
16	Malta	0	2 704	392	3 096
17	Netherlands	2 808	139 295	0	142103
18	Poland	1 566	292 134	131 863	425563
19	Portugal	2 992	71 294	11 606	85892
20	Romania	806	49 873	34 312	84 991
21	Slovakia	432	38 085	5 676	44193
22	Slovenia	618	38 985	0	39603
23	Finland	863	51 016	27 146	79025
24	France	11 882	1 028 446	0	1040328
25	Croatia	1 318	26 958	0	28276
26	Czech	1 250	130 671	0	131921
27	Sweden	2 050	579 564	0	581614
28	Estonia	115	10 427	47 985	58 527

An analysis of scientific publications [5, 6, 7] showed that a decrease in the operational costs of maintaining and repairing roads can be achieved by using cement concrete as a pavement material (Fig. 2).

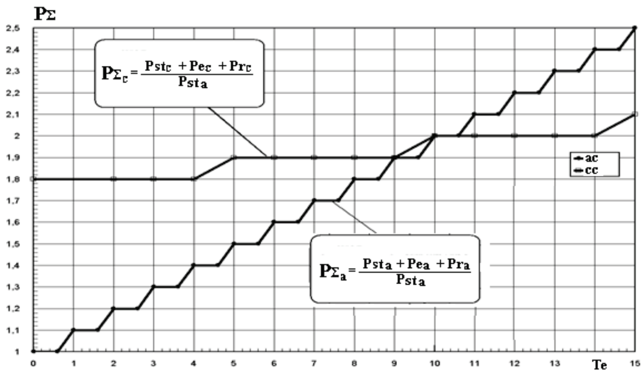

Figure 2 Relative construction cost (*PΣ*), maintenance and repair of roads bitominous with asphalt concrete and cement concrete (a - asphalt concrete, c - cement concrete, P_{st} - construction, P_e - content, P_r - repair, *Te* – road operation in time (in years), $P_{stc} = 1{,}8 \cdot P_{sta}$)

As it can be seen from Fig. 3, the total cost of construction and maintenance of highways made from cement concrete (c), after 10 years of operation, is lower than for the roads with asphalt concrete (a). Thus, the use of cement concrete coatings for the European Union countries reduces the cost of their maintenance and repair.

2 RESULTS AND DISCUSSION

An analysis of literary sources [7, 8, 9] showed that meeting the requirements on the durability of the cement concrete pavement for a highway can be achieved by a rational selection of its composition. The pavement is significantly affected by loads caused by traffic and climatic conditions.

The existing normative document EN 206-1 [10] (Tab. 2) does not take into account the frost resistance of the cement concrete pavement.

Table 2 Requirements for the material of the cement concrete pavement for roads (EN 206-1)

Characteristics	Demands
Water/cement (W/C)	0.45 ÷ 0.65
Class for compressive strength (MPa)	C 35/45 (45) ÷ C 40/50 (50)
Absorption of water, %	≥ 5
Frost resistance	-
Abrasion, mm	≥ 4
Air entrainment, %	4-7

With the purpose of studying the effect of the freeze-thaw temperature on the compressive strength and abrasion of the pavement material of cement concrete, researches have been conducted.

The purpose of the research was: the development of recommendations for a rational selection of the composition of the road pavement material of cement concrete, aimed at upgrading longevity, taking into account its frost resistance grade.

According to the goal, the following **tasks** were developed:

- the analyses of the climatic zones in which the road network of the European Union is located;
- the development of a research plan;
- the study of physico-mechanical and operational characteristics of the researched material of the road pavement;
- on the basis of the obtained data, the calculation of the complex of experimental-statistical models, which describe the physico-mechanical and operational characteristics of the road pavement material;
- on the basis of experimental statistical models, a method was proposed for selecting the rational compositions of the cement concrete pavement road material depending on the conditions of its application.

An analysis of the works [8, 9, 11] showed that the durability of the coating for highways made of cement concrete is significantly affected by the frost resistance of the material. The resistance of the pavement material to the effects of alternating temperatures is important for climatic zones with unstable negative temperatures (Fig. 2, Tab. 3). In these zones, throughout the entire winter period, repetitive cyclical freeze-thawing of the road pavement is happening.

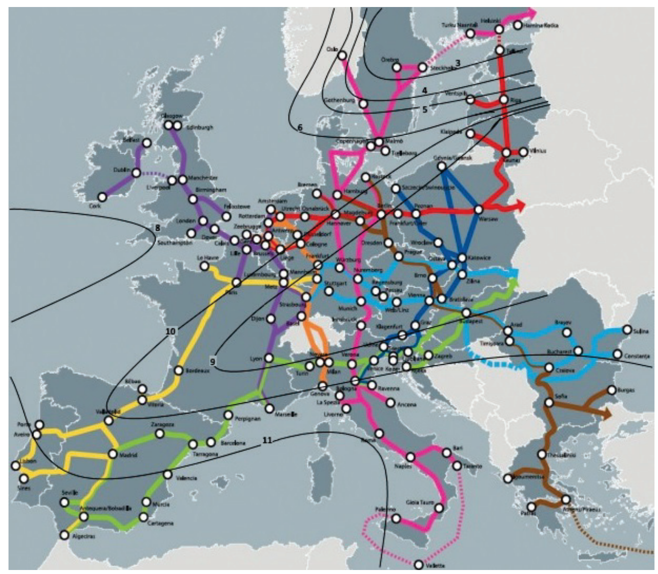

Figure 3 The location of the main roads of the EU countries in climatic zones

As it can be seen from Fig. 2, the roads of the European Union lie in different climatic zones. Therefore, different requirements for frost resistance should be imposed to the pavement material, depending on the climatic zones.

According to the works [7, 8, 9], an improvement in the frost resistance of cement concrete can be achieved by introducing an air-entraining additive into its composition, as well as a microsilica suspension filler. An increased resistance to the abrasion of the material is provided by the introduction of fibre material in the concrete. This composition allows the factors that influence the frost resistance of the pavement material to be determined (Tab. 4). The range of changes in the number of added components was determined on the basis of the recommendations of the MAPEI firm [12], an analysis of literature [11] and the personal experience of the author [9].

Table 3 Temperature range in winter time depending on the climatic zones

No. of zones	Celsius temperature (°C)	The number of freeze-thaw cycles	
		for 1 year	for 10 years
3	−40 … −34	4	40
4	−34 … −29	5	50
5	−29 … −23	5	50
6	−23 … −18	6	60
7	−18 … −12	8	80
8	−12 … −7	12	120
9	−7 … −1	20	200
10	−1 … +4	55	550
11	more +4	0	0

Table 4 Influencing factors and the range of their changes used in research

Impact factors			
x_1 –	air entraining agent additive Mapeplast PT-1		
x_2 –	polypropylene fiber MAPEFIBRE NS 12/ NS 18		
x_3 –	microsilicasuspension filler		
Range of factors change			
Levels of varying factors	x_1, l/m^3	x_2, kg/m^3	x_3, kg/m^3
Interval	0,142	0,3	7,5
Upper (+1)	0,285	0,6	15
Lower (−1)	0	0	0

The main characteristics of the additives and fillers used:

- air entraining agent additive Mapeplast PT-1 ("MAPEI"), its inclusion into the concrete mix provides an increase in the amount of the entrapped air (designed to increase the frost resistance of concrete);
- microsilica suspension, particle size 0.1-0.2 microns, specific surface area – 20 000 m^2/kg (designed to increase the strength of concrete and frost resistance, reduces abrasion and the permeability of concrete, etc.);
- polypropylene fibre - Mapefibre NS 12/NS 18 ("MAPEI"), diameter – 0.34 mm, fibre length 12-18 mm, density – 9,1×10-4 kg/m^3, tensile strength – 700 MPa, (increases the crack resistance of concrete and makes it resistant to abrasion).

The basic composition of the concrete mix for the manufacture of prototypes was determined by the method described in the article [9]:

- portland cement PC – I- H 500 - 470 kg/m^3;
- granite chippings (fractions 5÷20) - 1055 kg/m^3;
- sand (fineness modulus = 2.5) - 578 kg/m^3;
- superplasticizing admix Dynamon Easy 11 firms of "MAPEI" firms – 8.55 l/m^3;
- for adding water to the mix, distilled water was used.

The experiment plan is presented in Tab. 5.

At each point of the experiment plan, at least three experiments were conducted with the subsequent determination of the average value of the measurement result. To eliminate the influence of systematic errors caused by external conditions, the order of the experiments was randomized.

The experiments were conducted in the following sequence:

- the necessary amount of additives and fillers were added into the basic composition of the concrete mixture (Tab. 4);
- for each point of the experiment plan, the required number of samples was formed in the sizes of 0.1×0.1×0.1 meters and 0.07×0.07×0.07 meters [13];
- the obtained samples (Fig. 4a)) were maintained under the standard curing of a normal set for 28 days (t = 20 °C, W = 80%) [13];
- on the 28th day, samples of 0.07×0.07×0.07 meters were tested for an abrasion test (LKI-3 device) [14];
- the samples of 0.1×0.1×0.1 meters were tested for compressive strength [13];
- the part of the samples of 0.07×0.07×0.07 and 0.1×0.1×0.1 meters were tested for frost resistance in the freezer (in the freezing room temperature of −50 °C [15]);
- after testing for frost resistance (F50, F 100, F150, F 200), the samples (Fig. 4b)) were tested for the abrasion test and compressive strength [13, 14].

Table 5 The plan of the experiment and the compositions of the studied concretes

The plan of experiment				The composition of concrete		
No	x_1	x_2	x_3	PT-1, l/m^3	Fibre, kg/m^3	Microsilica suspension, kg/m^3
1	−1	−1	−1	0	0	0
2	−1	1	−1	0	0.60	0
3	0	0	−1	0.142	0.30	0
4	1	−1	−1	0.285	0	0
5	1	1	−1	0.285	0.60	0
6	−1	0	0	0	0.30	7.50
7	0	−1	0	0.142	0	7.50
8	0	0	0	0.142	0.30	7.50
9	0	1	0	0.142	0.60	7.50
10	1	0	0	0.285	0.30	7.50
11	−1	−1	1	0	0	15
12	−1	1	1	0	0.60	15
13	0	0	1	0.142	0.30	15
14	1	−1	1	0.285	0	15
15	1	1	1	0.285	0.60	15

a) b)

Figure 4 The material research: a) material samples prior to freezing and the thawing test; b) material samples after freezing and the thawing test (F 200)

The results of the experiments are presented in Tab. 6.

The convenience of the analysis for Tab. 6 is shown in a graphical form in the Figs. 5 and 6.

As it can be seen from the presented data (Fig. 5), the compositions used for the manufacture of the samples No. 1, 2, 3, 4 can be used as road pavement on the sections of roads that are not affected by the freeze-thaw.

Under the influence of the freeze-thaw temperature, the compressive strength of these samples decreases:

- for the sample No. 1 at: F50 – 3.1%, F100 – 8.1%, F150 – 9.5%, F200 – 14.2%;
- for the sample No. 2 at: F50 – 4.6%, F100 – 8.4%, F150 –11.8%, F200 – 15.6%;

- for the sample No. 3 at: F50 – 3.2%, F100 – 6.4%, F150 – 9.2%, F200 – 13.2%;
- for the sample No. 4 it comes down to: F50 – 1.9%, F100 – 5.4%, F150 – 8%, F200 – 9.3%.

The compressive strength of the remaining samples subjected to frost resistance tests, even after F200, was more than 50 MPa, which allows its use in all climatic zones.

Table 6 The results of the experiments on the compressive strength and abrasion under the cyclic effects of the freeze-thaw test (*F*)

The results of the experiments										
	$f_{\text{ck.cube}}$ (MPa)					G (kg/m²)				
No	$f_{\text{ck.cube0}}$	$f_{\text{ck.cube50}}$	$f_{\text{ck.cube100}}$	$f_{\text{ck.cube150}}$	$f_{\text{ck.cube200}}$	G_0	G_{50}	G_{100}	G_{150}	G_{f200}
1	2	3	4	5	6	7	8	9	10	11
1	50.25	48.70	46.20	45.50	43.15	0.062	0.065	0.067	0.068	0.071
2	52.60	50.30	48.40	46.70	44.80	0.030	0.033	0.036	0.038	0.039
3	51.80	50.20	48.60	47.20	45.20	0.048	0.050	0.052	0.054	0.057
4	50.10	49.15	47.40	46.10	45.45	0.067	0.069	0.072	0.074	0.076
5	53.40	52.90	52.00	51.10	50.35	0.033	0.036	0.039	0.042	0.045
6	54.60	53.90	52.70	52.00	51.45	0.037	0.040	0.043	0.045	0.048
7	54.20	53.80	52.40	51.20	50.35	0.048	0.053	0.057	0.059	0.061
8	55.20	54.70	53.90	52.00	51.45	0.038	0.040	0.042	0.044	0.047
9	54.70	53.15	52.50	51.70	50.75	0.029	0.032	0.035	0.036	0.039
10	53.75	53.00	52.10	51.40	50.50	0.037	0.039	0.041	0.043	0.046
11	56.50	56.10	55.40	54.90	53.90	0.058	0.060	0.063	0.066	0.069
12	57.80	57.00	56.10	55.20	54.30	0.025	0.028	0.033	0.036	0.039
13	55.45	55.00	54.10	53.25	52.80	0.037	0.039	0.043	0.045	0.048
14	54.90	54.00	53.25	52.30	51.80	0.045	0.048	0.054	0.057	0.062
15	55.00	54.50	54.00	53.85	53.20	0.029	0.031	0.034	0.036	0.038

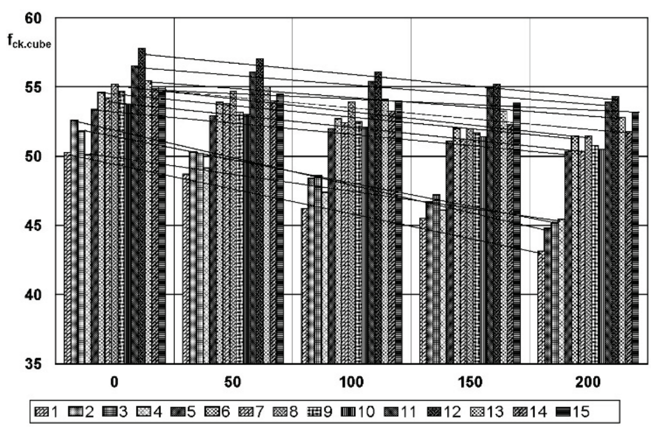

Figure 5 The results of the testing samples for abrasion before and after freezing and the thawing test (F0, F50, F 100, F150, F 200)

As it can be seen from Fig. 6, the abrasion of road pavement depends on the number of freeze-thaw cycles. An analysis of the data shown in (Fig. 6) proved that the samples of the material in which the loss of mass *G* was the following were the best in frost resistance:

- for the sample No. 2 at: F50 – 0.033 kg/m², F100 – 0.036 kg/m², F150 – 0.038 kg/m², F200 – 0.039 kg/m²;
- for the sample No. 5 at: F50 – 0.036 kg/m², F100 – 0.039 kg/m², F150 – 0.042 kg/m², F200 – 0.045 kg/m²;
- for the sample No. 9 at: F50 – 0.032 kg/m², F100 – 0.035 kg/m², F150 – 0.036 kg/m², F200 – 0.039 kg/m²;
- for the sample No. 15 at: F50 – 0.031 kg/m², F100 – 0.034 kg/m², F150 – 0.036 kg/m², F200 – 0.038 kg/m².

The worst indicators have the following samples: No. 1, No. 4, No. 7, No. 11 and No. 14.

As it can be seen from Figs. 5 and 6, the dependence of the change in compressive strength and the loss of mass of the specimens at abrasion under the influence of freeze-thaw temperatures have the appearance close to linear. This means that it is possible to significantly reduce the number of experiments by limiting them only to the extreme values of freeze-thaw resistance tests (Fig. 6, $f = 0$ and $f = 200$) with their subsequent linear approximation.

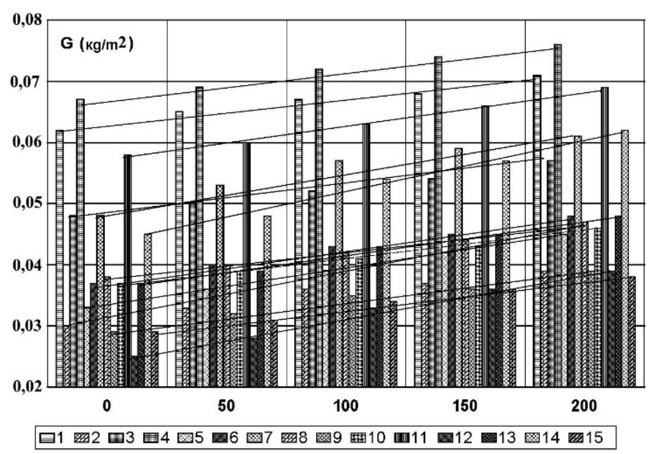

Figure 6 The results of the testing samples for compressive strength before and after freezing and the thawing test (F0, F50, F 100, F150, F 200)

The data used from Tab. 6 with the help of the Compex program [16] were obtained by ES-models in the form of a polynomial dependence of the form:

$$y = b_0 + \sum_{i=1}^{n} b_i x_i + \sum_{i=1}^{n} \sum_{k=i+1}^{n} b_{ik} x_i x_k + \sum_{i=1}^{n} \sum_{k=i+1}^{n} \sum_{l=k+1}^{n} b_{ikl} x_i x_k x_l + \ldots, \quad (1)$$

Where: y – the response function, b_0, b_{ik}, b_{ikl} – coefficients of the multiple regression equation, x_i – normalized value of the influence factor.

For the convenience of calculating mathematical models, the scale of the factors of influence was chosen so that the value of the upper level was equal to +1, and the lower to –1. The origin of the coordinates of the influence factors was transformed and the transition to the normalized value of each factor was made:

$$x_i = \frac{\left(\tilde{x}_i - \tilde{x}_{i0}\right)}{I} \quad (2)$$

Where: x_i – normalized value; $\tilde{x}_i$ – natural value; $\tilde{x}_{i0}$ – main level; I – variability interval:

$$I = \left|\tilde{x}_i - \tilde{x}_{i0}\right| \quad (3)$$

The description of the methods for calculating the coefficients of regression models is beyond the scope of this article, but if necessary, you can refer to the works [16, 17].

The calculated mathematical models describing the change in the compressive strength ($f_{\text{ck.cube0}}$, $f_{\text{ck.cube200}}$) and abrasion (G_0, G_{200}) of the pavement material before and after the freezing thawing resistance test of the test samples (F 200) are presented in Tab. 7.

Table 7 Mathematical models describing the change in the compressive strength ($f_{\text{ck.cube0}}$, $f_{\text{ck.cube200}}$) and abrasion (G_0, G_{200}) of the pavement material before and after the freezing thawing resistance test

No	Response function	ES-models	
1	$f_{\text{ck.cube0}}$ (MPa) =	$54.49 - 0.46x_1 - 0.63x_1x_3 + 0.75x_2 - 0.53x_2x_3 + 2.15x_3 - 0.71x_3^2$	(4)
2	G_0 (kg/m^2) =	$0.04 + 0.002x_1x_2 - 0.002x_1x_3 - 0.01x_2 + 0.002x_2x_3 - 0.04x_3 + 0.004x_3^2$	(5)
3	$f_{\text{ck.cube200}}$ (MPa) =	$51.29 + 0.28x_1 - 0.85x_1x_3 + 0.24x_2 - 0.31x_2x_3 + 2.69x_3$	(6)
4	G_{200} (kg/m^2) =	$0.05 + 0.001x_1x_2 - 0.002x_1x_3 - 0.01x_2 + 0.003x_2^2 + 0.001x_2x_3 - 0.003x_3 + 0.006x_3^2$	(7)

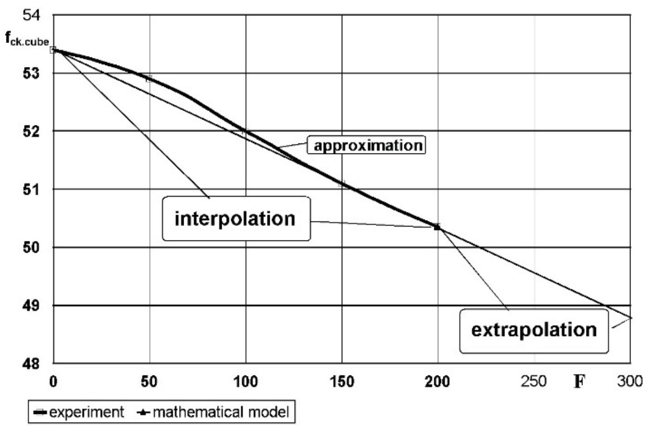

Figure 7 The example of using the mathematical models No. 1 and 3 for assessing the resistance of the sample No. 5 to the effect of the freeze-thaw cycles (F) on compressive strength

The obtained mathematical models allow us to determine the indicators of compressive strength and the abrasion of the road pavement material with a different combination of influence factors lying in predetermined intervals (Tab. 7).

To convert the results of the calculations using mathematical models into real physical quantities, a reverse transition from a standardized scale to a natural scale was made, using Eq. (2). The illustration of the use of mathematical models (for the sample No. 5) is presented in the Figs. 7 and 8.

The calculations of the compressive strength and abrasion with consideration of the freeze-thaw resistance for cement concrete pavements are made in the following sequence:

- the substituting formulas 4 ÷ 7 (Figs. 7 and 8) and the data of the influence factors (Tabs. 4 and 5) will determine the values - compressive strength ($f_{\text{ck.cube}}$) and abrasion (G), when exposed to the freeze-thaw temperature (at $F = 0$ and $F = 200$ cycles);
- through the obtained values, linear interpolation is performed and if necessary, extrapolation of the results is performed (Figs. 7 and 8);
- according to the Fig. 3 and Tab. 3, the number of freeze-thaw cycles for one year is determined;
- depending on the cycle life of automotive coating and the number of freeze-thaw cycles, resistance to alternating temperatures for the entire life time of the pavement is determined;
- deferring the values of freeze-thaw cycles along the ordinate axis (OF), we build the axis perpendicular to the intersection with the direct defining $f_{\text{ck.cube}}$, and similarly for G.

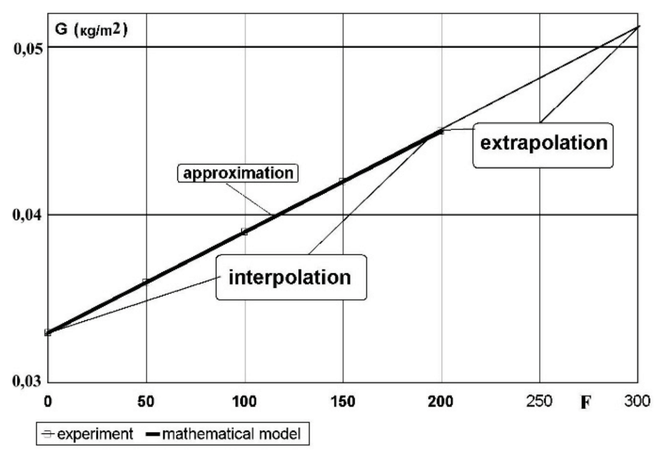

Figure 8 The example of using the mathematical models No. 2 and 4 for assessing the resistance of the sample No. 5 to the effect of freeze-thaw cycles (F) on abrasion

3 CONCLUSIONS

The researches have allowed the proposition of a method for determining the magnitude of changes in the compressive strength and weight loss of samples when the road pavement material is abraded under the influence of freeze-thaw temperatures.

An analysis of climatic zones in which the EU road network is located was carried out in order to determine the necessary freeze-thaw resistance of the road pavement material for each of them.

The study of changes in the properties of the pavement material depending on the number of freeze-thaw cycles has been carried out.

The recommendations for a rational selection of the composition of the pavement material of the cement concrete depending on the requirements for the freeze-thaw resistance were developed.

On the basis of the experimental statistical models obtained, a method is proposed for selecting the rational compositions of cement concrete road pavement materials, depending on the required freeze-thaw resistance.

When conducting research, additives and fillers from the MAPEI firm were used, which were kindly provided to the author by a representative of the company. If necessary, similar results can be obtained for the components from other manufacturer firms.

4 REFERENCES

[1] The European transport corridors [Electronic resource]. – Access mode: http://dergachev.ru/geop_events/210515-02.html#.XHZyGNDSjmZ (Available: 07 March 2019)

[2] The classification and description of typical road maintenance defects [Electronic resource]. – Access mode:http://www.steps.ru/article/klassifikatsiya_i_opisanie_tipichnyh_defektov_soderzhaniya_avtomobilnyh_dorog (Available: 09 March 2019)

[3] Shaikh Sameer J., Kanahya Bhutada, Sainath Poharkar, Devidas Chavade, & Kedarnath. (2018). Road Defects and Highway Maintenance. IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), 15(2), Ver. II (Mar. - Apr.), 43-47. www.iosrjournals.org

[4] The length of highways in Europe [Electronic resource]. – Access mode: https://autotraveler.ru/spravka/road-length-in-europe.html#.XJFbDDpS__8. (Available: 05 March 2019).

[5] Solonenko, I. P. & Bratcheko, P. G. (2016). The harmonization of the regulatory framework of Ukraine with international requirements for road coverage. *The Sixth International Scientific and Practical Conference. Metrology, technical regulation, quality: achievements and prospects - OGATRK*, Odesa, 63-65.

[6] Vyrozhemskyi, V., Krayushkina, K., & Bidnenko, N. (2017). Durable high strength cement concrete topping for asphalt roads. *IOP Conference Series: Materials Science and Engineering*, 236, 012031. https://doi.org/10.1088/1757-899X/236/1/012031

[7] Pogorelov, S. N. & Semenyak G. S. (2016). Frost Resistance of the Steel Fiber Reinforced Concrete Containing Active Mineral Additives. Procedia Engineering, 150, 1491-1495. https://doi.org/10.1016/j.proeng.2016.07.088

[8] Delatte, N. J. (2014). *Concrete Pavement Design, Construction and Performance*, 2nd Ed., CRC Press, London. https://doi.org/10.1201/b17043

[9] Solonenko, I. P. (2015). The structure and properties of modified cement concrete coatings for highways, Dissertation. Sciences: spec. 05.23.05 *Construction materials and products* / I. P. Solonenko. OGASA. Odessa, 155 p.

[10] Concrete - Part 1: general of technological requirements, production and quality control. (EN 206-1) Per. from English Yu. S. Volkov. - Brussels, 2000. - 68 p.

[11] Mardani-Aghabaglou, A., Hosseinnezhad, H., Boyacı, O. C., Arıöz, Ö., Yaman, İ. Ö., & Ramyar, K. (2014). Abrasion resistance and transport properties of road concrete. Access mode: https://www.researchgate.net/publication/276334935_abrasion_resistance_and_transport_properties_of_road_concrete

[12] MAPEI. Agent additive for concrete and cement mortars. Access mode: http://ukrpolystroy.com.ua/shop/dobavka-mapei/

[13] DSTU B V.2.7-214:2009. Building materials. Concrete Methods of determining the strength of control samples. Kyiv, 2009, 35 p.

[14] DSTU B V.2.7-212:2009. Building materials. Concrete Methods of definition of erosion. Kiev, 2009, 8 p.

[15] DSTU B V.2.7-49-96:1997. Building materials. Concrete. The accelerated methods for determining frost resistance during multiple freezing and thawing. Kyiv, 1997, 10 p.

[16] Voznesensky, V. A. (1981). *The statistical Methods for Experimental Planning in Techno-Economic Research* / V. A. Voznesensky. 2nd ed. M.: Finance and Statistics, 263 p.

[17] Voznesensky, V. A. (1989). The numerical methods for solving construction and technological problems on a computer / V. A. Voznesensky, T. V. Lyashenko, B. L. Ogarkov. Kyiv: Vishcha School, 327 p.

Author's contact:

Iryna SOLONENKO, PhD, Head teacher
Odessa State Academy of Civil Engineering and Architecture,
4, Didrikhsona St., 65029 Odessa, Ukraine
Tel./Fax: +380974666579,
E-mail: odarina08@rambler.ru