

PAPER • OPEN ACCESS

The factors defining the efficiency of earthed shields made of electroconductive cementing compositions for the electrocorrosion protection

To cite this article: O A Pluhin *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **708** 012100

View the [article online](#) for updates and enhancements.

You may also like

- [4th International Conference on Sustainable Futures: Environmental, Technological, Social and Economic Matters](#)
S O Semerikov, S M Chukharev, S I Sakhno et al.
- [Development of career guidance quests using WebAR](#)
D S Shepiliev, S O Semerikov, Yu V Yechkalo et al.
- [The use of GIS in renewable energy specialist's learning](#)
I S Zinovieva, Anna V Iatsyshyn, V O Artemchuk et al.

PRIME
PACIFIC RIM MEETING
ON ELECTROCHEMICAL
AND SOLID STATE SCIENCE

HONOLULU, HI
October 6-11, 2024

Joint International Meeting of
The Electrochemical Society of Japan
(ECSJ)
The Korean Electrochemical Society
(KECS)
The Electrochemical Society (ECS)

Early Registration Deadline:
September 3, 2024

**MAKE YOUR PLANS
NOW!**

The factors defining the efficiency of earthed shields made of electroconductive cementing compositions for the electrocorrosion protection

O A Pluhin^{1,5}, D A Plugin², V V Kasianov³, O O Skoryk⁴ and A V Nykytynskiy²

¹ Structural Mechanics and Hydraulics Department, Ukrainian State University of Railway Transport, Feuerbach sq.7, Kharkiv61050, Ukraine

² Building Materials and Structures Department, Ukrainian State University of Railway Transport, Feuerbach sq.7, Kharkiv61050, Ukraine

³ Department of land administration and geoinformation systems, O M Beketov National University of Urban Economy in Kharkiv, Marshala Bazhanova str.17, Kharkiv 61002, Ukraine

⁴ Railway Survey and Design Department, Ukrainian State University of Railway Transport, Feuerbach sq.7, Kharkiv 61050, Ukraine

⁵ Email: plugin0785@gmail.com

Abstract. The factors that define the efficiency of earthed coating shields made of the Portland cement-based electroconductive cementing composition were experimentally studied to provide the electrocorrosion protection. It was established that the current intensity is increased by the three orders of magnitude as the current flows through the water-saturated earthed coating shield made of the Portland cement-based electroconductive composition. This fact confirms the feasibility of the use of such shields to drain the leakage currents that are considerably increased achieving unsafe values especially in wet weather. It was also established that protective shield properties depend on the ratio of the contact area of the coating-shielded steel earth electrode to the area of entire coating shield. As this ratio is increased the intensity of the current flowing through the structure reinforcement and concrete is decreased and the intensity of current flowing through the earthed coating shield is increased. It confirms the efficiency of the use of earthed coating shields made of the Portland cement-based electroconductive compositions to provide the electrocorrosion protection caused by leakage currents, for example for such structures as railway d. c. current-electrified passenger platforms.

1. Introduction

Railway structures are operated under especially unfavorable conditions; these are simultaneously exposed to heavy dynamic loading and atmospheric influence; very often these are exposed to the influence of the corrosive environment and on electrified railway sections these are subjected to an intensive electric effect induced by leakage currents and stray currents (Figure 1, a, b). There is an opinion that the electric effect of leakage currents results in the electrocorrosion of only underground metal structures and networks and railway structure reinforcement and it can only be possible on d.c. current-electrified railway sections with the voltage of 3 kV [1, 2]. However, it was established in [3] that the concrete exposed to the action of unidirectional pulsed electric potential and certain current



that is induced during periodic train passages is also subjected to the electrocorrosion that results in the electromigration leaching of $Ca(OH)_2$ and crack formation (Figure 1, b) and the intensity of these processes depends on the current intensity.

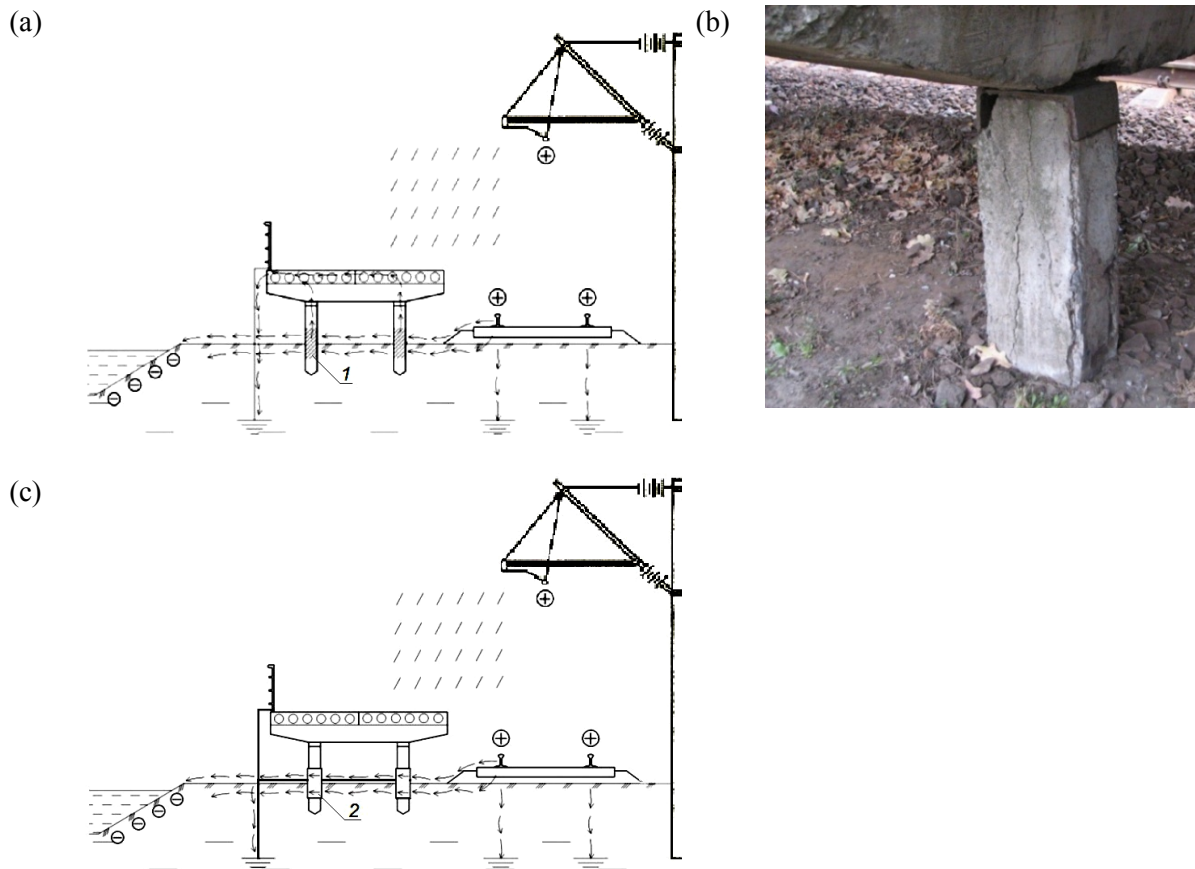


Figure 1. Electrocorrosion and the electrocorrosion protection of reinforced concrete risers for high passenger platforms: a – the diagram of the passage of the leakage current from the rails through platform structures and the metal enclosure earthing in rainy weather; b – the cracks formed in the risers due to the reinforcement electrocorrosion; c – the diagram of the passage of leakage current from the rails through the risers protected by earthed coating shields; 1 – the electrocorrosion damage zone; 2 – the earthed coating shield

To avoid the electrocorrosion of underground structures, the anode or cathode protection, i.e. the electrodraining is used [4]. It is suggested in [3] that the structures should be protected by earthed electroconductive shields (figure 1, b) that can be considered as a variety of electrodraining. The fabrication of such shields in the form of metal injection rings or jackets enables the restoration or improvement of the bearing capacity of the structure. However, metal injection rings are considered to be an expensive and labor-intensive constructive-&-technological solution and it is advisable only in the case of the need for the revival of the bearing capacity of damaged structures or their reinforcement.

Different researchers were involved in the development of electroconductive concretes and compositions based on mineral binders [5-13] that were mainly intended for heating elements [5, 7-12]. To provide the electrocorrosion protection it was suggested in [3] that the Portland cement-based electroconductive composition of a penetrative action with the complex chemical additive and electroconductive filler should be used instead of metal rings; its mixture was developed and the type of electroconductive filler was selected and its content was defined and the papers [14, 15] delve into

the efficiency of this composition. This composition forms the electroconductive coating on the structure surface due to the use of graphite filler [14] and the use of the complex chemical additive provides the colmatation by hydration products [15] and an increase in the electric resistance of the surface of concrete layer of the structure itself. It was established that the protection provided by the earthed coating shield made of this composition provides a two-fold decrease in the intensity of current flowing through the structure concrete and reinforcement because it flows mainly through the shield.

However, in addition to the composition mixture and the content of electroconductive filler the coating shield efficiency depends also on other factors, for example on the humidity (damped) condition. It was also assumed that the efficiency of earthed coating shield depends on the ratio of the contact area of the coating-shielded steel electrode to the area of entire coating shield, but this issue was not studied. Hence, the studies of these dependences are an urgent task.

The purpose of studies was to establish the factors that have an impact on the efficiency of the earthed coating shield made of the Portland cement – based electroconductive composition, including the dependence of the efficiency on the damped condition of the coating and also on the ratio of the contact area of the coating-shielded steel electrode to the area of entire coating shield.

2. Materials and research methods

Consideration was given to the Portland cement – based composition with the complex chemical additive and the graphite filler added to the mixture with the following mass fraction [3, 15]: Portland cement CEM I 42.5 N – 32 (31.0–33.0), the quartz sand with the fineness module of 1.2–1.5 – 53 (52.1–56.0); the complex chemical additive was present on average in the amount of 5% including sodium nitrate – 1 (0.15–1.0); calcium salt of weak inorganic acid in the amount of 1 (0.2–1.33); calcium chloride – 0.5 (0.10–0.67); sodium sulfate – 0.5 (0.10–0.67); sodium carbonate – 0.5 (0.10–0.67); calcium hydroxide – 0.5 (0.10–0.67); corrosion converters – 0.1 (0.025–0.17); corrosion inhibitor – 0.1 (0.025–0.17); superplasticizer – sulfonaphthalene formaldehyde – 0.3 (0.05–0.34); and graphite of a lubricating grade GS-1 – 10%.

The efficiency of electroconductive compositions contained by earthed coatings was studied using the developed original techniques and the experimental plant (figure 2). The plant consists of the construction model, in particular the prism made of the heavy concrete with the compression strength of 20 MPa equipped with the released up rod made of reinforcing steel and encased into it. The model concrete corresponds to the structure concrete between its faces or to the protective layer concrete between the earthed reinforcement and the construction face. This prism was placed into the model of wetted ground, i.e. very fine sand was poured into the metal vessel. The coating shield with the total area of S_{ec} (Figure 2, a) was applied in advance on the part of the prism dipped into the ground. The contact of the coating shield with earthed conductor was provided through the steel contact plate with the area of S_{se} (Figure 2, b). The ratio of the contact area of steel electrode with the earthed coating shield S_{se} to that of the entire coating shield S_{cs} was defined as

$$x = S_{se}/S_{cs} \times 100 \%. \quad (1)$$

The prism without the earthed coating shield served as the reference specimen (figure 2, c).

The current that leaks to the structure from DC sources, for example, from the electrified rail track was induced (simulated) by the application of the difference of potentials of 40 V between the vessel and the reinforcing rod in the prism and the intensity of current flowing through the model concrete and reinforcement I_{cr} and the earthed coating screen I_{es} was measured by the ammeters (digital multimeters Sanwa PC510, Figure 2, a, b) connected to the circuit.

The indicator of the efficiency of protection from leakage currents was the value of the drop in the intensity of current flowing through the reinforcement and concrete due to the use of the earthed coating shield; the percentage difference ΔI between I_{cr} in the reference specimen and I_{cres} in the specimen with the earthed coating shield was defined as:

$$\Delta I = (I_{cr} - I_{cres})/I_{cr} \times 100 \%. \quad (2)$$

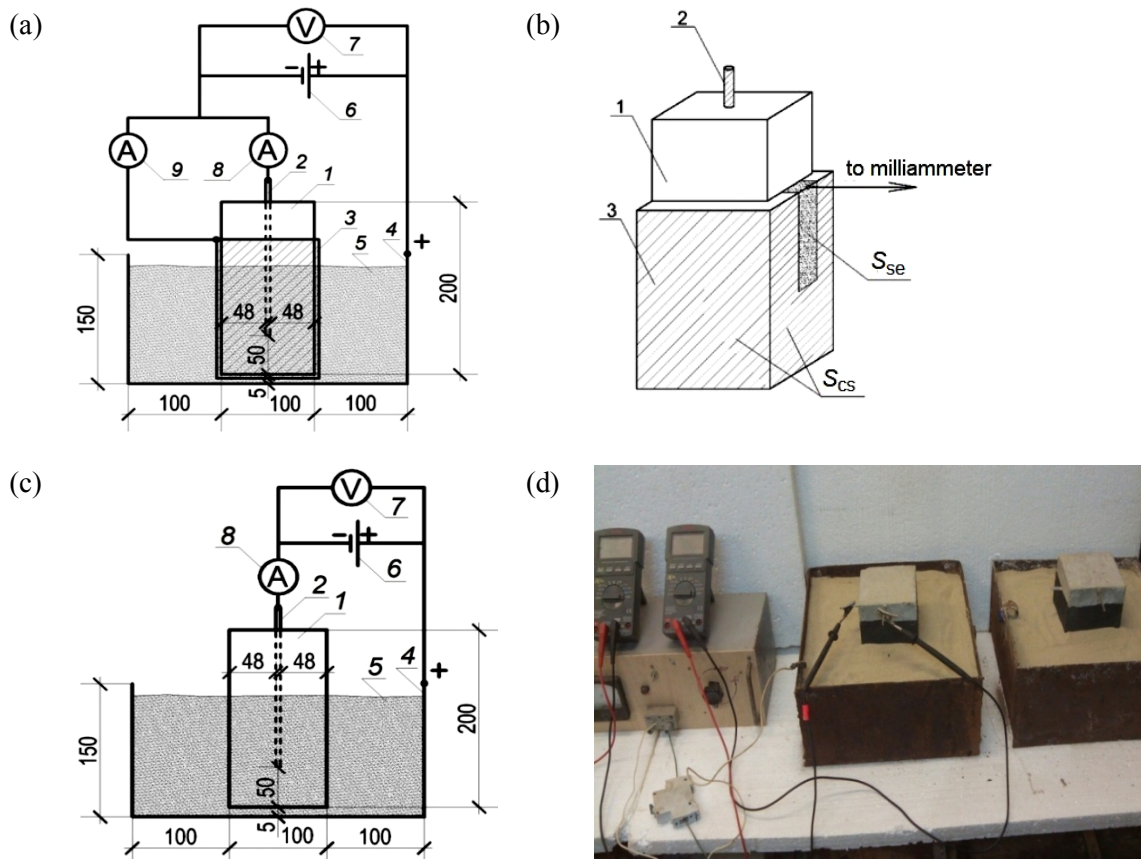


Figure 2. The plants used for experimental investigations of the efficiency of the shields made of electroconductive compositions: a, b, c – diagrams of the plant with the reference specimen (the construction model) with no shield (a) and the test specimen (the construction model) with the shield made of electroconductive composition (b, c); d – the view of experimental plants; 1 – the metal vessel; 5 – the damped sand; 6 – the current source; 7 – voltmeter; 8 – milliammeter for the measurement of the intensity of current flowing through the protective shield and the ground I_{es} .

To study the dependences of the efficiency of the earthed coating shield on its damped condition and the ratio x of the contact area of steel electrode with the earthed shield to that of the entire coating shield a series of the specimens with a different value of S_{se} and accordingly x was fabricated. The measurements were initially taken for the dry state of the ground and then the ground was saturated with water and the measurements were taken during 240 hours with the initial periodicity of 1 hour and afterwards 5, 12 and 24 hours. The obtained data are given in the form of the relationship diagram for the intensity of current flowing through the concrete and reinforcement I_{cr} , the intensity of current flowing through the protective shield I_{es} and the value of the drop in the intensity of current flowing through the model concrete and reinforcement with the protective coating shield in comparison to the model with no protective shield as a function of time.

3. The research data and their discussion

The research data are given in figure 3.

It can be seen in Figure 3, a–d that in the case of dry ground (at the beginning of the experiment at $t = 0$) the intensity of current flowing through the model reinforcement and concrete I_{rc} was minimum

both for the unprotected structure model and for the structure model protected with the coating shield. The intensity of the current flowing through the coating shield was also minimum. After the water saturation of the ground and the coating shield, accordingly, the current intensity tripled and therefore it is reasonable to use earthed coating shields for the drainage of leakage currents that show a multiple increase attaining unsafe values especially in wet weather.

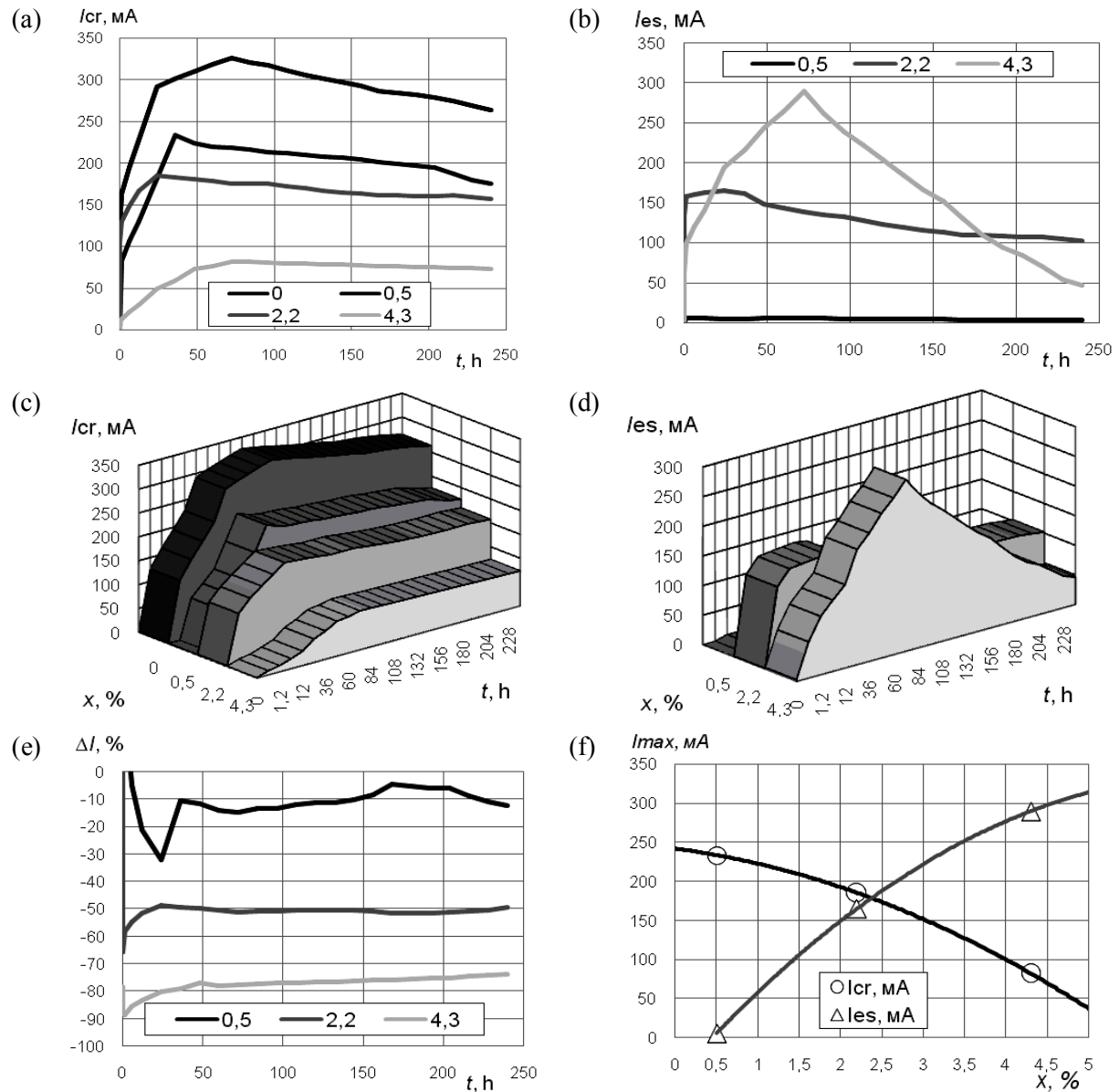


Figure 3. The relationships for the indicators of the efficiency of earthed coating shields made of the Portland cement-based electroconductive compositions as a function of a different ratio of the contact area of steel electrode with the coating shield to the area of entire coating shield x (0 – with no protective shield for the mixture component ratio of 0.5; 2.2; 4.3): a–d are the relationships for the intensity of current flowing through the model reinforcement and concrete I_{cr} (a, c), the intensity of current flowing through the protective shield I_{es} (b, d), e – a change in the intensity of current flowing through the model reinforcement and concrete ΔI_{cr} as a function of time from the moment of the water saturation of the ground t ; f – the dependence of I_{cr} and I_{es} on the ratio of the contact area of steel electrode with the coating shield to the area of entire coating shield x .

Figure 3, a, c, d show that the protection provided by the earthed coating shield resulted in a decrease in the intensity of current flowing through the model reinforcement and concrete I_{rc} due to the flow of the portion of current I_{ps} through the protection shield (Figure 3, b, c). In comparison to the unprotected model the value of current flowing through it is lower by 49 to 66%.

Figure 3, e shows that protective shield properties depend on the ratio of the contact area of steel electrode with the coating shield to the area of entire coating shield x ; with an increase in this value the current intensity of I_{rc} is decreased and the value of I_{es} is increased. When the ratio of the contact area of steel electrode with the coating shield to the area of entire coating shield is $x = 0.5\%$ the current intensity of I_{rc} is decreased for ΔR_{rc} by 10 to 15%, for $x = 2.2\%$ by 50 to 55%, and for $x = 4.3\%$ by 75 to 80%.

It confirms the efficiency of earthed shields used for the corrosion protection of structures, for example passenger platforms exposed to leakage currents that cause the corrosion.

4. Conclusions

The obtained experimental data show that the intensity of current I_{es} flowing through the Portland cement-based electroconductive composition is increased three-fold due to the water saturation of the earthed coating shield made of that composition. It confirms the appropriateness of the use of such shields for the drainage of leakage currents induced on rail tracks that are multiply increased attaining unsafe values in wet weather.

It was established that protective screen properties depend on the ratio of the contact area of steel electrode with the coating shield to the area of entire coating shield x . As this ratio x is increased the intensity of current I_{rc} flowing through the structure concrete and reinforcement is decreased and intensity of current flowing through the earthed coating shield is I_{es} is increased. At the ratio of $x = 0.5\%$ the value of I_{rc} is decreased by 10 to 15% for $x = 2.2\%$ it is decreased by 50 to 55%, and for $x = 4.3\%$ it is decreased by 75 to 80%. It confirms the efficiency of earthed shields used for the corrosion protection of structures, for example passenger platforms exposed to leakage currents that cause the corrosion.

References

- [1] Staroselskii A A 1978 *Electrocorrosion of reinforced concrete* (Kyiv: Budivel'nik)
- [2] Kotelnikov A V 1986 *Stray currents of electrified transport* (Moscow: Transport)
- [3] Pluhin O A, Borziak O S, Martynova V B and Khaliushev O K 2013 *Electric effects on the concrete: Eds A A Plugin and M M Zaichenko* (Kharkiv: Fort)
- [4] Strizhevskii I V, Belogolovskii A D, Dmitriev V I et al 1990 *Corrosion protection of underground metal structures* (Moscow: Stroyizdat)
- [5] Serdiuk V R, Lemeshev M S and Khrystych O V 1997 Physical and chemical specific features of the formation of the structure of electroconductive concretes *Visnyk of Vinnitsa Polytechnic Institute* **2** 5-9
- [6] Khrystych O V and Lemeshev M S 1998 Formation of microstructure of concrete for protection against ionizing radiation *Visnyk of Vinnitsa Polytechnic Institute* **2** 18-23
- [7] Pushkareva E K and Guzii S G 2000 Microstructure of resistive composition materials in the system $\beta\text{-C}_2\text{S-SiC-C-Na}_2\text{O}\cdot\text{SiO}_2\cdot m\text{H}_2\text{O}$ *Resources, materials, structures and buildings: RDTU* **5** 82-85
- [8] Pushkariova K K and Guzii S G 2001 Simulating the processes of the production of nonlinear high-resistance composite materials in the $\beta\text{-C}_2\text{S-SiC-C-Na}_2\text{O}\cdot\text{SiO}_2\cdot m\text{H}_2\text{O}$ system *Budivnytstvo: DIIT* **9** 54-57
- [9] Pushkariova K K and Guzii S G 2002 Investigation of the physicochemical processes of the formation of a dielectric matrix in a system $\beta\text{-C}_2\text{S-Na}_2\text{O}\cdot\text{SiO}_2\cdot m\text{H}_2\text{O}$ *Scientific and practical problems and modeling and forecasting of supersonic situations: KNUBA* **5** 23-29

- [10] Lopanov A N, Fanina E A and Guzeeva O N 2014 Cement-quartz electrically conductive composites based on graphite dispersions *ARPJ Journal of Engineering and Applied Sciences* **9** 2250-2253
- [11] Lopanov A N, Guzeeva O N, Prushkovsky I V and Tikhomirova K V 2014 Technology of electrically conductive composites of alkaline earth metals carbonates and carbon dispersions *ARPJ Journal of Engineering and Applied Sciences* **9** 2275–2278
- [12] Lopanov A N, Fanina E A and Guzeeva O N 2016 Regulation of electrical and rheological properties of heterogeneous systems based on quartz sand and graphite by mechanical activation of quartz sand *Vestnik MGSU* **8** 78–87
- [13] Smirnova O M 2017 Obtaining the High-performance Concrete for Railway Sleepers in Russia *Procedia Engineering* **172** 1039-1043
- [14] Pluhin O, Plugin A, Plugin D, Borziak O and Dudin O 2017 The effect to f structural characteristics on electrical and physical properties of electrically conductive compositions based on mineral binders *Matec Web of Conf.* **116** 01013
- [15] Plugin A A, Pluhin O A, Borziak O S and Kaliuzhna O V 2020 The Mechanism of a Penetrative Action for Portland Cement-Based Waterproofing Compositions *Proc. of CEE 2019. Lecture Notes in Civil Engineering* **47** 34-41