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Polymer-cement mortar for protection of buildings against electrical influences

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Abstract. In recent decades, the number of sudden structural failures of buildings and structures being in operation and under construction has increased in the world. Generally, most of the experts associate these failures with the following reasons: design errors; errors and violations made during construction; and poor maintenance. In our opinion, another reason for the sudden structural failure of buildings and structures and the characteristic of the areas where they occur is the periodic accumulation and alteration of excess negative electric charge and the electric field of the Earth in crust fractures zones, near artificial sources of electricity, DC powered transport, rivers and large water reservoirs. To protect buildings and structures in hazardous excess negative charge areas, a polymer-modified mortar was developed based on carbamide resin cured with chlorine iron, with the addition of a superplasticizer and fly ash from thermal power plants. Theoretical, experimental and practical results of the study are provided.

1. Introduction

In recent decades, the number of sudden structural failures of buildings and structures being in operation and under construction has increased in the world. Generally, most of the experts associate these failures with the following reasons: design errors; errors and violations made during construction; and poor maintenance (in Ukraine especially in the 1990s). Descriptions of the mechanisms of most such structural failures are either absent or inaccurate, the measures taken to restore the destroyed buildings and structures are often ineffective, and the structural failures occur again. Some scientists hypothesize unconventional causes of such destruction associates them with the special properties of soils under the structures, processes and effects that occur in them, in particular, tectonic disturbances, planetary ripple, “rock burst”, and acoustic resonance absorption. These effects can be detected using the developed and recognized spectral seismology method [1, 2]. Giving credit for the importance of the results of such studies, it is still worth noting that, in our view, the connection between these effects and, actually, the structural failure of buildings and structures in specific known cases is insufficiently substantiated.



2. Research methodology

The methodology of theoretical research is based on the provisions of colloid chemistry and physico-chemical mechanics of materials [3], as well as on the provisions of the scientific school of professors A M Plugin and A A Plugin. Their applicability is due to the fact that colloid chemistry and physico-chemical mechanics consider surface phenomena, in particular, the electrical characteristics of the surface of disperse systems of various sizes, including the Earth, where electric surface phenomena, processes and regularities also prevail. In experimental studies, standard, original, and physicochemical methods were used.

3. Results of research

In our opinion, another reason for sudden structural failures of buildings and structures and the characteristic of the areas where they occur is the periodic accumulation and change of excess negative electric charge and the electric field of the Earth in crust fracture zones [4-5], near artificial sources of electricity and DC-powered transport [6-10], rivers and large water reservoirs.

As far as we know, the excess electric charge and the electric field of the Earth accumulate as a result of thermal diffusion of electrons from the hot core of the Earth to the cold surface. Excess means surpassing the equilibrium electric field of the Earth, with intensity of -130 V/m, respectively, of a charge -130 C/m². Experimentally established deviations from equilibrium values are within the range from -1000 and even -2000 to $+200$ V/m.

The mechanism of action of the excess charge is the emergence of additional forces from electrostatic repulsion between negatively charged surfaces and particles inside the structures of buildings. Usually such structures are located on the upper floors of buildings. Launches of space rockets, during which a huge amount of rocket fuel is burned, also contribute to the accumulation of excess negative charges, which change over time, causing a very significant distribution of electric charges heightwise. This can be confirmed by the increase in the number of construction site accidents in 1985-1995 (figure 1), when launches the heavy Space Shuttle were most active, and after 2005, when China began to launches of heavy space ships. We believe that the accumulation of excess electric charges and, consequently, the construction site accidents, was also influenced by an increase in solar activity, for example, in 1965.

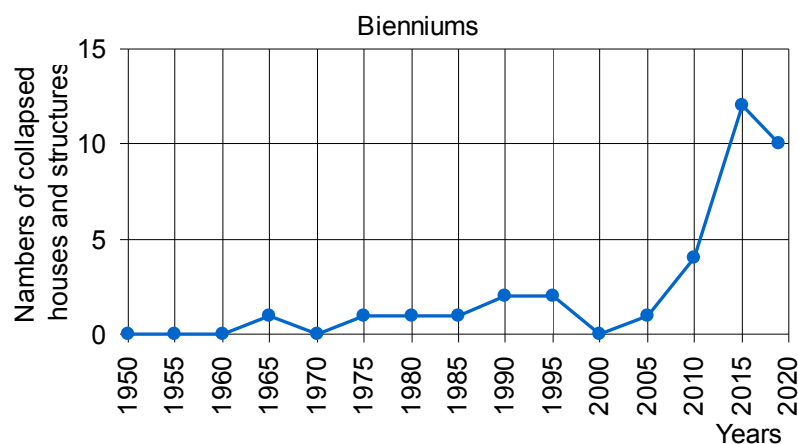


Figure 1. The number of collapsed buildings and structures in the period from 1950 to 2019 (by two-year periods).

Within the developed mechanism of damage under the action of forces caused by the excess electric charge ΔG accumulated in the structures, the stress in the structures of buildings was calculated.

4. An example of calculation of stresses from excess negative charge in the structures of buildings

Input data:

- the wall of a brick building measuring 6×3 m, 0.4 m thick;
- excess negative charge $\Delta G = 1000 \text{ C/m}^3$ (electric field strength 1000 C/m^3).

4.1. Central tension

Tensile stress with uniform accumulation of excess negative charge in the body of the material:

$$f_0 = E \cdot \Delta Q, \text{ (N)}, \quad (1)$$

$$f_0 = 10^3 \cdot 10^3 = 10^6, \text{ (N)}.$$

By definition, the electric field strength is the force acting on a unit charge at a height of 1 m. Accordingly, a charge in 1 m^3 of a structure is:

$$\Delta Q = 10^3, \text{ C/m}^3.$$

Therefore, the tensile force from excess charge in a 6 m long strip with a section of 1 m^2 is:

$$f_0 = 3 \cdot 10^3 \cdot 10^3 = 3 \cdot 10^6, \text{ (N)},$$

and tensile stress is:

$$\sigma_t = \frac{3 \cdot 10^6 / 2}{1^2} = 1.5 \cdot 10^6 \left(\frac{\text{N}}{\text{m}^2} \right) = 1.5 \text{ MPa},$$

which significantly exceeds the standard tensile strength of the brickwork.

4.2. Bending tension

The bending stress in the outer wall of the building ΔG occurs between its excess charges on the outer and inner surfaces, with $G_{\text{in}} = 0$ (when the excess negative charge begins to enter the wall from the outside).

Maximum moment acting in a strip of the wall with a width of 1 m is:

$$M = \frac{f_0 \cdot l^2}{8}, \quad (2)$$

where l is the length of the wall (6 m).

In view of (1):

$$M = \frac{10^6 \cdot 6^2}{8} = 4.5 \cdot 10^6 \text{ (N} \cdot \text{m)}.$$

Bending stress is:

$$\sigma_b = \frac{M_b}{W}. \quad (3)$$

Moment of resistance of the wall is:

$$W = \frac{bh^2}{6}, \quad (4)$$

$$W = \frac{0.4 \cdot 1^2}{6} = 0.067 \text{ (m}^3\text{)}.$$

Stress in the middle of the strip is:

$$\sigma_b = \frac{4.5 \cdot 10^6}{0.067} = 6.716 \cdot 10^7 \left(\frac{\text{N}}{\text{m}^2} \right) = 67.16 \text{ (MPa)}.$$

This is a very high stress, far exceeding the bending strength of masonry (<1 MPa).

The stresses in the joints of the walls and structures will be even higher.

Thus, the stresses in the structures of buildings from excess negative charge can far exceed the stresses from the design loads.

A mechanism and patterns for the occurrence of excess charges, including those destroying the masonry of the building were developed, according to which the accumulation of excess electric charges from leakage currents, electric fields and natural and anthropogenic charges on the building structures can:

- cause separation of charges and formation of high dipole moments along the height of buildings; in areas of excess negative charges, contribute to cracking due to the repulsive forces in the hydrosilicate gel of the cement stone of the mortar and concrete, including due to the occurring stresses and strains in the structures of walls and floors;
- contribute to damage to walls due to the addition of the load from the weight of the structures and electric forces caused by the separation of charges heightwise;
- contribute to flooding of the foundations and basements due to the electroosmotic transport of groundwater and the waters of nearby reservoirs, figure 2.

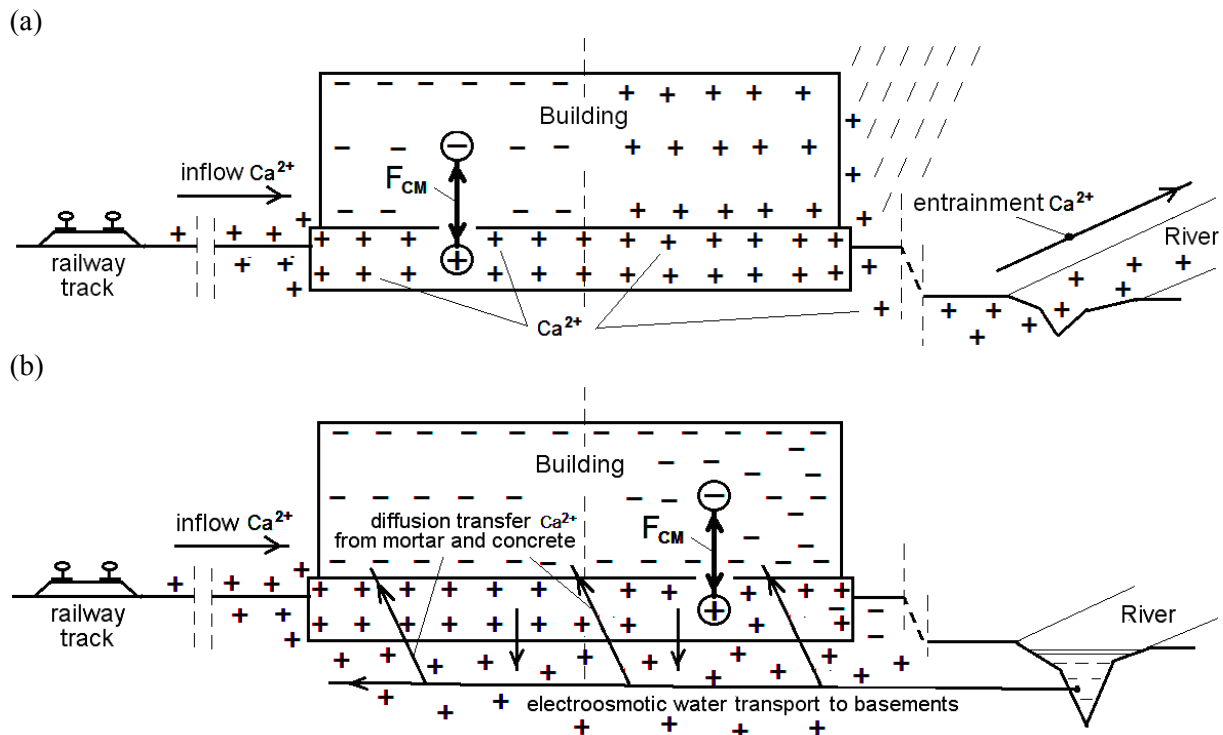


Figure 2. The diagram of formation of excess electric charges on the building structures from Ca²⁺ cations transfer as a result of leakage currents, precipitation and nearby water streams: a – separation of charges along the height of the building and the emergence of electric forces F_{cm} , which are added to the loads and cause damages of walls of the lower floors; b – electroosmotic water transport from reservoirs to basements.

As a result of the conducted study, understanding of the mechanism of occurrence and effect of excess electric charges on the stone and concrete structures of buildings and constructions was further developed, in particular, an improved pattern of leakage current flow through structures of buildings and constructions was developed in which in wet and rainy weather current flows not only through the foundations, but also through the structures of the walls and floors and further in the grounding bars, and causes intensive leaching of the masonry and concrete mortar (electric corrosion), as well as their polarization – the accumulation of excess charges.

5. Development of a polymer-modified mortar

To protect buildings and structures in the hazardous negative charge areas, a polymer-modified mortar (PMM) was developed based on a carbamide resin cured with $FeCl_3$ with addition of superplasticizer and fly ash of thermal power plants.

The good protective properties of the polymer-modified mortar against electric corrosion and the destructive effect of excessive electric charges are substantiated, in particular:

- it is established that curing of carbamide resin in polymer-modified mortar with chlorine iron and adding fly ash provides an increase in the number of positively charged crystalline hydrates in the cement hydration products, that bind excess negative charges and prevent their proliferation inside the structure;

- it is determined that adding fly ash to the polymer-modified mortar provides an increase in the ability of the mortar to polarize due to the giant low-frequency dielectric constant of its particles and, thus, to increase the electrical resistance of the mortar and its ability to prevent the proliferation of excess electrical charges inside the structure;

Experimental studies of the effect of excess electric charges created by the potential difference on the physicochemical, electrophysical, and other properties of cement-sand mortar (CSM) and the developed polymer-modified mortar (PMM) were performed which determine their resistance and protective properties, in particular, the strength development (figure 3) and changes in electrical resistance of PMM with 2% $FeCl_3$.

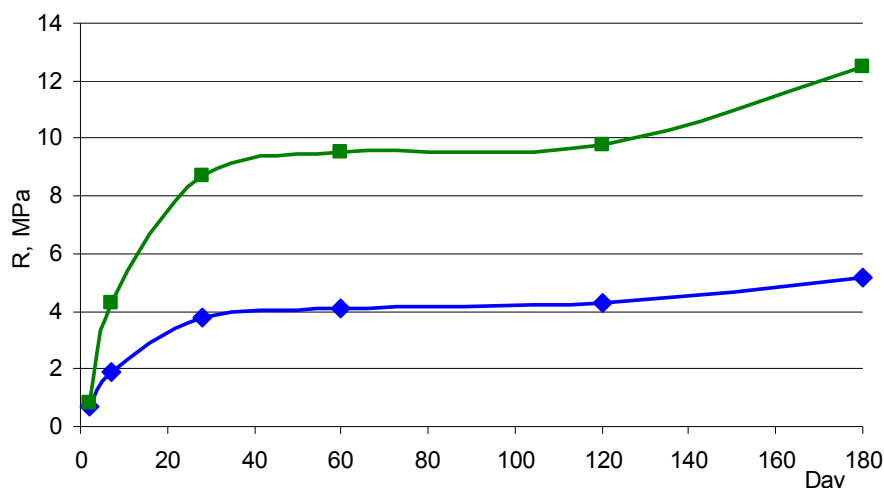


Figure 3. Kinetics of changes in the properties of a polymer-modified mortar with 2% $FeCl_3$: bending strength (—◇—) and compression strength (—□—).

The operational properties of PMM were studied in comparison with the CSM counterpart: swelling and shrinkage, adhesion, deformability, crack resistance, frost resistance, water resistance, and electrical resistance. It was determined that no shrinkage is observed in 14 days. Adhesion, frost

resistance, crack resistance of PMM are significantly higher than those of a conventional cement mortar. Deformability of PMM and CSM is almost the same.

Figures 4 and 5 show the results of a change in the electrical characteristics of the masonry as a result of the above effect (figure 6). According to figure 5, the current and voltage at the electrode in the middle of the PMM masonry height are much lower than the current and voltage in the CSM masonry.

Based on the results of the study, a set of measures was developed and implemented to protect and restore the structures of buildings and structures operated in conditions of flooding and under the effects of leakage currents from rail tracks, as well as excess charges created by them.

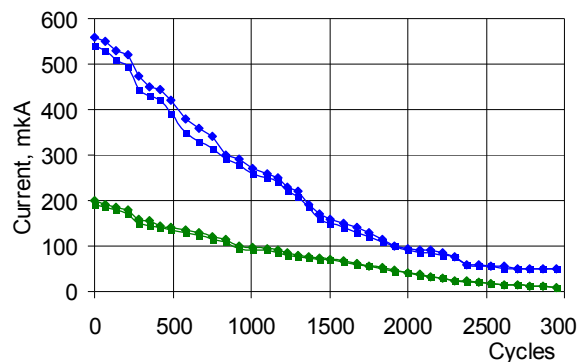


Figure 4. Change of the current through the masonry at the beginning (—◆—) and at the end (—■—) of the cycle; upper diagrams – CSM; bottom diagram; PMM.

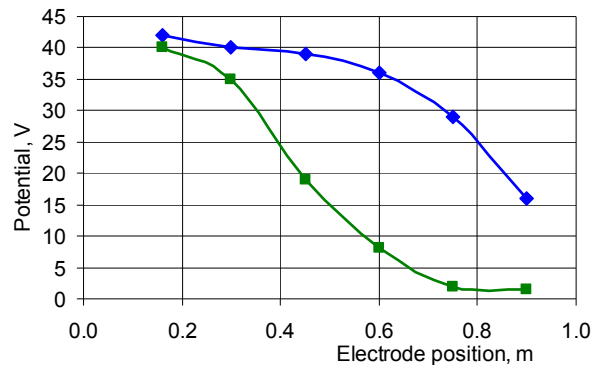


Figure 5. Dependence of the potential at the electrode on its position in the masonry heightwise (distance from the bottom of the masonry to the electrode) after 3 thousand cycles: CSM (—◆—); PMM (—■—).

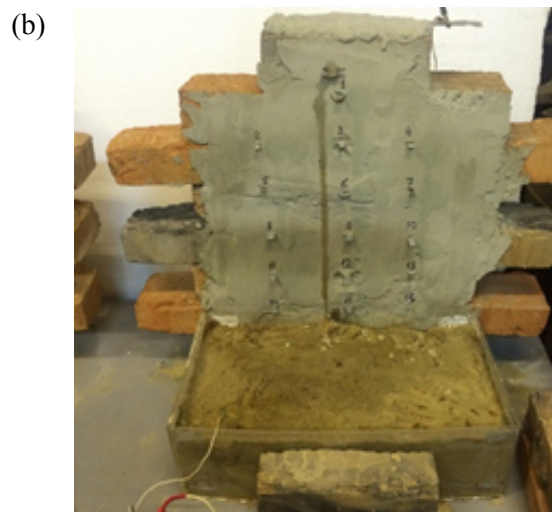
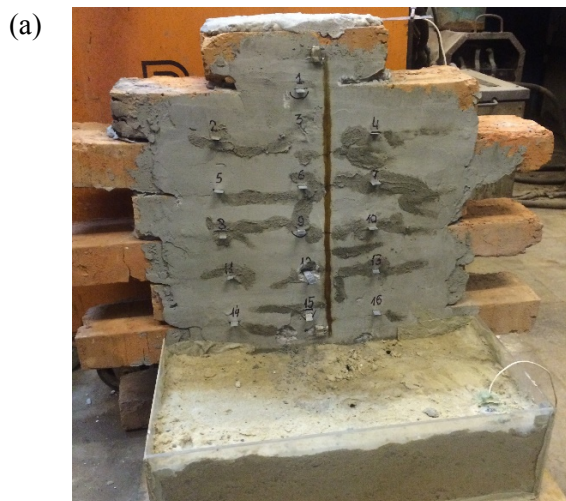


Figure 6. Models: fragments of masonry with brickwork and plaster mortar: a – cement and sand mortar (CSM); b – polymer-modified mortar (PMM).

6. Conclusion

The nature of the occurrence of excess electric charges on the structures of buildings and structures from leakage currents and stray currents, electric fields and natural and anthropogenic charges, their effect on crack formation in masonry and the respective damage to buildings are given. The

composition of the polymer-modified mortar (PMM) based on carbamide resin cured with $FeCl_3$ and addition of fly ash was developed, as well as the manufacture technology and the protection technology for masonry of buildings and structures. Its operational properties are much better than those of conventional plaster mortars, it also has high protective properties against the destructive effect of excess negative charges on the structures of buildings and constructions located in the areas of accumulation of this charge.

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