Effective modern methods of protecting metal road structures from corrosion

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Abstract. In the article the ways of protection of barrier road constructions from various external influences which cause development of irreversible corrosion processes are considered. The author studied modern methods of action on metal for corrosion protection and chose the most effective of them: a method of directly affecting the metal structures themselves. This method was studied in more detail in the framework of the experiment. As a result, the article describes the experiment of using a three-layer polymer coating, which includes a thermally activated primer, an elastomeric thermoplastic layer with a spatial structure, and a strong outer polyolefin layer. As a result of the experiment, the ratios of the ingredients for obtaining samples of the treated metal having the best parameters of corrosion resistance, elasticity, and strength were revealed. The author constructed a regression equation describing the main properties of the protective polymer coating using the simplex-lattice planning method in the composition-property diagrams.

1. Introduction
Road metal structures are an obstacle that partially removes the energy of impacts, prevents the machine from converting from the road. Also, barrier structures allow zoning of car parks. Thanks to the fences, a full movement is carried out, as the metal structures of various forms divide the roadway into strips, thereby performing the function of preventive action. Separation of vehicle flows, the allocation of a pedestrian zone are important functions of road structures. On dangerous road fragments, additional protection is provided for motorists and passengers through metal mechanisms. All these factors are indisputable proof of the need to create road barrier structures made of particularly strong materials [1, 2].

However, very often municipal administrators are faced with the problem of the untimely replacement of existing fences with more modern and efficient ones, as road repairs have been carried out quite recently and it is inappropriate to make additional budgetary investments in almost new fences. In this case, modern methods of protecting metal structures from various types of external influences come to the aid of municipal authorities: temperature effects, atmospheric and ground moisture effects, air movement, exposure to aggressive chemical impurities, and others.

This study examines ways to protect metal structures from external influences, such as corrosion. Corrosion of metals is a process of their destruction, caused by external chemical or electrochemical effects of the medium. [3, 4]

Corrosion is a powerful disaster of metals. Losses from it are huge. Despite the applied protection, about 10% or more 10 million tons of metal are annually turned into rust. However, these direct losses
do not reflect the true volume of all losses. In the end, due to corrosion on roads, not only metal, but also building structures (barrier fences) die, the cost of which is much higher than the cost of the metal expended on them. The damage from corrosion is determined not only by the loss of metal and huge costs for cleaning, repair, replacement of metal products and structures, but also for the loss of reliability and efficiency of construction objects [5].

2. Materials and Methods
Existing ways to protect the metal from corrosion are divided into two types: 1) the ways in which they affect the environment, making it less aggressive for the design, and 2) ways to directly affect the metal itself. You can also use these methods in a modern manner. [6, 7]

In this paper, we will dwell in detail on the second method (effect on metal) - the development and operation of protective coatings used to stop the corrosion process.

In the world practice of metal coatings the most widely used is galvanizing. Undoubted advantages of zinc coatings for the protection of steel and cast iron products are: 1) relatively low cost; 2) slow dissolution due to electrochemical reactions.

Five types of zinc coatings are known [8, 9]: 1) galvanic; 2) metallization; 3) hot-dip galvanizing; 4) diffusion; 5) zinc-filled "cold galvanizing".

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Analysis of all properties of polymeric materials showed that in the construction it is economically expedient to use them in the manufacture of load-bearing structures of high corrosion resistance, floor covering, wall finishing, thermal insulation of enclosing structures and technological equipment, sealing joints and seams in large-panel buildings, waterproofing roofs and foundations, - technical equipment and pipes, as well as for anticorrosion works. [10, 11]

To bearing structures it is possible to include road plates, floor coverings of industrial buildings. An example can serve as multilayered panels, which are used as walling for walls and coatings. They are a wooden or aluminum frame, lined on both sides with hard fibreboard and chipboard with a water-resistant polymer coating or sheet plastic, the gap between the shells is filled with foam or plastic foam insulating panels. Such designs are widely used in industrial construction most often in the reconstruction and repair of highways. [12]

Of great interest are pneumatic structures (soft shells) that perform the enclosing functions of the arch. The designed dome shape and load-bearing capacity is provided by the injected air at a pressure of 0.1 - 1.0 kPa. The material for pneumatic structures is the non-reinforced and reinforced mesh (kапрон, лавсан, метал) polymer films, fabrics coated or impregnated with polymers, high-strength steel ropes. Soft shells are used to cover markets, sports halls. When filled with water or water in combination with air, these structures are used as dams.

The advantages of rigid shells are that they can have both positive and negative curvature of the surface. Spans covered by shells can reach 90-110 m, the mass of 1 m2 of coating is 7-20 kg. The material for rigid shells is sheet glass plastics, aluminum and steel profiles, glued wooden beams and to provide insulation - polystyrene.

The construction of roads raises the issue of ensuring the corrosion resistance of load-bearing and self-supporting structures. The only material that meets the set of specified properties is polymer concrete. It is obtained by intensive mixing in the concrete mixer of heated aggregates (sand, gravel), polymer resin and additives. The resulting mass is placed in a mold, compacted and kept at a temperature of up to 100°C. Polymer concrete possess high mechanical strength (Rc = 90-110 MPa, Ras = 9-11 MPa), chemical resistance, dust free, hygienic, water-resistant. All these properties predetermine the use of these materials for the manufacture of columns, floor slabs, piece materials for flooring. In the production of polymer solutions in the composition there is no large aggregate (crushed stone).
Depending on the type of polymer binder, polymer concrete can be furan, polyester, epoxy; containing reinforcement is called armopolymer concrete. Depending on the material of the reinforcement, steelpolymer concrete (steel reinforcement) and glass-reinforced concrete (fiberglass reinforcement) are distinguished. Armature can be in the form of rods, wires or individual fibers, evenly distributed throughout the volume - disperse reinforcement. As disperse reinforcement, short thin threads and fibers (fibers) of metal, glass, rocks and polymers are used. If dispersed reinforcement is used in polymer concrete, then concrete is called fiber-polymer concrete.

3. Results
Consider the use of a three-layer polymer coating used for corrosion protection of large diameter pipes, which includes a thermally activated primer, an elastomeric thermoplastic layer with a spatial structure, and a strong outer polyolefin layer.

The basis of the research is a simplex-lattice method of planning on the composition-property diagrams. The curing process of the samples was carried out under different temperature conditions. From the samples, prototypes were made which were subjected to tensile tests at various temperatures (room temperature - 20 °C and negative temperature - 30°C). [13, 14]

The results of the conducted experiments were statistical data on the behavior of the polymer coating, depending on its composition and external conditions of use. The obtained data made it possible to construct a regression equation describing the main properties of the polymer coating (1):

\[ Y = 3.41x_1 + 1.42x_2 + 14.2x_3 - 1.26x_1x_2 - 25.86x_1x_3 - 18.68x_2x_3 + 58.2x_1x_2x_3 \]  (1)

Studies of the equation have shown, and the experimental data, obtained in Figure 1, confirmed the conclusion that the main contribution to the strength characteristics of the samples is made by epoxy resin, and when the proportion of resin SF-342A and rubber in the compositions is increased, the tensile strength of specimens under normal conditions decreases noticeably. The tensile strength of the samples under tension varies within the limits of 1.42 ... 3.14 MPa.

Figure 1. Dependence of the tensile strength of specimens on the component ratio at a negative temperature.
It can be seen from the graphs that epoxy resin makes the main contribution to the strength of the samples, and the role of rubber is about an order of magnitude smaller. The smallest share in the index of strength is made by the resin SF-342A. This is due primarily to the technology of processing polymers in products, as well as the properties of individual components.

Thus, the strength of vulcanizers from ED-20 resin is 2 ... 3 times higher than the strength of samples from rubber or resin SF-342A. The most optimal combination is the use of ED-20 resin with rubber, and the use of epoxy resin pairs - SF-342A and rubber - SF-342A are reducing factors.

But at the same time, the use of all constituent primers in a certain ratio leads to an increase in the strength of the samples. The relative deformation index varies within the range of 20 ... 32% and has a pronounced maximum (30 ... 32%) corresponding to the central part of the selected area of research. It is found that with increasing ED-20 resin content while reducing the soda Erzhanov rubber and resin SF-342A tensile strength increases. With an increase in the amount of rubber in the formulations with a moderate content of epoxy resin and with the introduction of a large amount of SF-342A resin, the tensile strength decreases smoothly [15]. The change in the relative strain passes through a maximum with the ED-20 resin content of about 30 ... 32%. This characteristic is most influenced by the content of rubber. This is evidenced by the values of the coefficients in the regression equation, calculated from the results of the experiment [16].

The results of a study on the behavior of samples at negative temperatures are shown in Figure 2.

![Figure 2](image_url)

**Figure 2.** Dependence of the tensile strength of specimens on the component ratio at a negative temperature.

Samples from the obtained compositions, regardless of the initial temperature during the cyclic bending tests, showed satisfactory results and withstood more than 50 loading cycles without visible signs of failure.

**4. Discussion**

As a result of the study, the regression equation coefficients were obtained, which allow describing the behavior of the polymer coating depending on its composition and external conditions [17, 18, 19].

The obtained proportions of the ingredients of the polymer primer base allowed to obtain samples having the best indices of elasticity of strength, high density, good adhesion to a polyethylene film,
regardless of its thickness. The tensile strength of the specimens under normal conditions was 3.0-3.6 MPa with a relative deformation within the range of 30-32% [20, 21, 22].

5. Conclusions
The peculiarity of the universal primer for the protection of metal road structures against corrosion has been identified, which consists in the fact that simultaneous use of thermal composition and primer solve several important tasks at once.

Namely:
- insulation and protection of the surface from the effects of moisture, the effects of the atmosphere;
- the creation of a reliable, durable and elastic adhesive layer;
- use of thermotaking polyethylene as a part of a universal primer provides a dense prileganiem of an epoxy compound to metal and the corrosion agents provides protection of the surface against influence;
- essential decrease in costs of work on isolation and repair, including factory covering and some other.

Heat-shrinkable polyethylene in the universal primer ensures a tight fit of the epoxy compound to the metal and protects the surface from corrosive agents [23];
- the significant reduction in the costs of insulation and repair work, including factory coverage, and a number of others [24, 25, 26].

Thus, we have obtained some theoretical dependences, which allow describing the behavior of a polymer coating depending on its composition and external conditions. The practical recommendations on the composition of the polymer prime have been developed.

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