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# Model of Aging Coatings Based on Hereditary Factors

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**Abstract**

The kinetics of the aging of coatings with the manifestation of hereditary factors. A model of aging

**Keywords**: aging, bond strength, hereditary factors, factors additivity

## Introduction

Test results for a painted surface of buildings' walls indicate that a coating's resistance of buildings' exterior walls, among other factors, is determined by a staining time.

So, if a colorific composition is applied in April and May, when there is an intense UV radiation with high humidity of a coverage, due to the migration of moisture from a substrate side, the ageing of the coating occurs at a higher rate in comparison with an alternative paint in August-September. One of the reasons for this behavior is a manifestation of hereditary factors, i.e., change the properties of protective-decorative coatings is determined by an actions' order of climatic factors [1, 2].

## The results of studies

For a confirmation of this assumption the following experiment has been done. Samples of protective - decorative coverings on a mortar's base were tested. The water dispersion (VD-AK-111) and the polyvinyl-acetate-cement (PVAC) paint were used. It was studied an influence of thermal ageing as well as humidifying in various sequence for properties of coverings – relative hardness (the VD-AK-111covering), durability of cohesion with the substrate (the PVAC covering). The samples were humidified during 800 hours and then were exposed to thermal ageing at the temperature of 60C during 240 hours. As there was a change of a factor impact sequence, the parameters of environment were kept stable.

The coefficient of additivity Ka was used to estimate the influence of the factors quantitatively. It is determined by a ratio of changes in the properties for a given sequence of the factors to the sum of the changes caused by each factor separately.

$$K_a\,(t,W) = \Delta f(t,W)/\{\Delta f(W)+\Delta f(t)) \qquad (1)$$

$$K_a\,(W,t) = \Delta f(W,t)/\{\Delta f(W)+\Delta f(t)), \qquad (2)$$

where $\Delta f(W)$, $\Delta f(t)$ - change properties of the coatings after moistening and thermal ageing respectively;

$\Delta f\ (W,t)$ - change properties of the coatings after moistening and subsequent ageing;

$\Delta f\ (t,W)$ - change properties of the coatings after thermal ageing and subsequent moistening.

Changing of the coatings' properties $\Delta f$ was defined as a difference between an initial parameter (before ageing) and a parameter after ageing.

The results are shown in the Table 1.

The results of these studies suggest that in the process of moistening an exponential decline in the relative hardness of the VD-AK-111 coatings and decreasing adhesion of the PVAC coatings is observed.

Thermal ageing of the VD-AK-111 coatings at a temperature of 60°C during 240 hours causes an increase in the relative hardness of the VD-AK-111 coatings from 0.45 to 0.48. In the PVAC coatings decrease of adhesion to the substrate during thermal ageing is observed.

There is a different expression of the climatic factors' impact to the change of the coverings' properties. For the PVAC coatings, if the thermal ageing goes after the moistening, it causes a smaller change of strength of adhesion in comparison with the sum of the individual effects.

If thermal ageing goes before moisturizing for 240 hours, there is a weakening of the destructive effects of the factors. It is observed for the VD-AK-111 coatings a somewhat different character depending on the order of influence of the climatic factors. If thermal ageing goes after wetting with the same intensity of exposure factors, the cumulative effect of changes in the relative hardness of the coating is an additive effect of climatic factors. If thermal ageing goes before moisturizing, there is a weakening of the impact of factors.

The results of calculations testify, that value of the additivity coefficient changes depending on the sequence of influence of the climatic factors and a kind of the covering (tabl. 1). So, Ka (W, t) =1 for the VD-AK-111coverings at sequence (W, t), i.e. takes place additive action of factors. At sequence (t,W) factor Ka (t, W) =0,82.

**Table 1**
**The additivity coefficient at various sequence of influence of climatic factors**

| coating type | $K_a(W,t)$ | $K_a(t,W)$ |
|---|---|---|
| VD-AK-111 | 1 | 0,82 |
| PVAC | 0,85 | 0,72 |

For the PVAC coverings, at sequence (W, t), value $K_a$ (W, t) is equal 0,85, and at sequence (t, W) value $K_a$ (t, W) is equal 0,72.

Thus, at the identical combinations of the working climatic factors and their intensity, the value of the additivity coefficient for the various coverings can be different.

A decrease or increase in time of humidifying and thermal ageing in comparison with described in the given clause, obviously, will change numerical values of the additivity coefficient, i.e. an amplification or easing of the sequentially working factors can be observed.

Thus, during ageing, the numerical values of the coverings' properties at the moment of time "t" are defined also by their kinetics of their previous change, dependent on intensity of the climatic influences (intensity of the UV-irradiation, temperature, humidity of air, etc.), i.e. the prehistories of ageing [3]. For the account of influence of the hereditary factor for the change of the coverings' properties, we will consider that at present time t the parameter of quality U (t) represents the sum of two items:

$$U(t)=V(t)+\int_{o}^{t} V(\tau)K\,(t,\tau)d\tau \qquad (3)$$

The first item represents the instant component, the second item - the inherited component. It is defined as follows. The memoirs on a condition of coverings' properties at the moment of time $\tau$ and $\tau+d\tau$, belonging to the past, should be proportional to size of property of a covering at the moment of time $\tau$ -V ($\tau$) and durations of an interval $d\tau$. For the account of a prehistory of ageing the function of forgetting K $(t,\tau)$ is entered. If K $(t,\tau)$ aspires to the final limit at $t\to\infty$ and thus comes nearer to this limit quickly enough it is possible to count, that the result of the previous influence is reduced to addition of a decreasing component $\int_{o}^{t}V(\tau)K\,(t,\tau)d\tau$, and memory of it is kept forever, thus in a covering there are irreversible changes.

In equation (3), V (t) is the function characterizing the process of changing the properties of the coating without account of the hereditary factor. Function K $(t,\tau)$ characterizes hereditary properties of a material and is a nucleus of heredity. We represent the function K $(t,\tau)$ as a product of two functions

$$K\,(t,\tau)=h(\tau)\varphi\,(t-\tau), \qquad (4)$$

where h (τ) is the function describing the ageing process of the covering

Function h (τ) is usually approximated by the equation

$$h(\tau) = C_{пр} + C_o / \exp(-\beta\tau) \qquad (5)$$

Constant Cпр characterizes the limit of the coatings' properties.

φ(t-τ) is the function describing the effect of duration of exposure, and characterizes the hereditary properties of the coating

Function φ (t) changes within the limits of $0<\varphi(t) < 1 \quad 0 < t < \infty$

After some mathematical transformations the model of ageing of the coatings can generally be approximated by the expression below

$$U(t) = A\exp(-\alpha t) - \alpha \int_o^t A\exp(-\alpha\tau)\{C_{пр} + C_o/\exp(-\beta t)\}(1-\exp(-(t-\tau)))d\tau \qquad (6)$$

Numerical values of A и $\alpha, \beta, C_{пр}$ и $C_o$ in models of ageing of some protective - decorative coverings received in view of the hereditary factor are obtained. Various numerical value of the function reflecting influence of the hereditary factor on change of properties of coverings is established. Presence of a polymeric component in structure of a covering promotes some decrease {reduction} in "memory" that obviously is caused by faster course relaxational processes in structure of coverings. Numerical values of the function reflecting influence of the hereditary factor, depend on age, the aspiration of a nucleus to a final limit with increase in age "t" is observed.

We have analyzed the change of the function characterizing the influence of hereditary factors on the properties of the coatings, depending on the type of coating and ageing. We used the PVAC (polyvinyl-acetate-cement) paint, the polymer- lime and lime paint.

Samples after curing of coatings subjected to the following types of ageing: hydration, heat ageing at 50 ° C, as well as the combined effect of climatic factors (4 hours freezing at -40 ° C; thawing for 2 hours at a temperature of 40 ° C; moistening for 2 hours at a temperature of 20C; UV radiation for 16 hours). As an indicator of the quality we used the adhesive strength of coatings. The research results and calculations are given in tabl.1, 2.

For these types of coatings equation (2) has the form

**1) for the PVAC coatings**

Thermal ageing

$$R_{сц}=1,97\exp(-0,0002t)-0,0002\int_o^t 1,97\exp(-0,0002\tau)\{0,75+1,22/\exp(-0,0009t)\}*(1-\exp(-(t-\tau)))d\tau \qquad (3)$$

Moistening

$$R_{сц}=1,99\exp(-0,0003t)-0,0003\int_o^t 1,99\exp(-0,0003\tau)\{0,75+1,24/\exp(-0,0015t)\}*(1-\exp(-(t-\tau)))d\tau \qquad (4)$$

**2) for the lime paint**

Thermal ageing

$$R_{сц}=1,1exp(-0,003t)-0,003{}_{o}\int^{t}1,1(-0,003\tau)\{0,1+0,99/exp(-0,008t)\}(1-exp(-(t-\tau)))d\tau \qquad (5)$$

Moistening

$$R_{сц}=0,98exp(-0,00085t)-0,00085{}_{o}\int^{t}0,98(-0,00085\tau)\{0,25+0,75/exp(-0,01t)\}(1-exp(-(t-\tau)))d\tau \qquad (6)$$

**3) for the polymer-lime paint**

Thermal ageing

$$R_{сц}=1,57exp(-0,0005t)-0,0005{}_{o}\int^{t}1,57exp(-0,0005\tau)\{0,75+0,84/exp(-0,0004t)\}*(1-exp(-(t-\tau)))d\tau \qquad (7)$$

Moistening

$$R_{сц}=1,66exp(-0,0005t)-0,0005{}_{o}\int^{t}1,66exp(-0,0005\tau)\{0,91+0,75/exp(-0,003t)\}*(1-exp(-(t-\tau)))d\tau \qquad (8)$$

The analysis of experimental data testifies, that influence of the hereditary factor on change of durability of adhesion of coverings, ambiguously. So, the maximal value of function ${}_{o}\int^{t} V(\tau) K(t,\tau) d\tau$ is typical of the limy covering in the process of thermal ageing. After thermal ageing for 200 hours the numerical values are 0.313 MPa for the lime coating. In the process of moistening, the effect of hereditary factors on the change in the strength of adhesion of coatings affected to a lesser extent.

So, after 200 hours of humidifying of a limy covering value of function ${}_{o}\int^{t} V(\tau) K(t,\tau) d\tau$ is 0,147 MPa.

Table 1

Value of the function, which characterizes the influence of hereditary factors on the adhesion strength of some coatings, depending on the type of ageing, MPa

| Coating's type | Ageing Time, hours | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 25 | 50 | 75 | 100 | 125 | 150 | 175 | 200 |
| PVAC paint | 0,018<br>0,028 | 0,037<br>0,056 | 0,056<br>0,084 | 0,074<br>0,111 | 0,092<br>0,137 | 0,109<br>0,162 | 0,127<br>0,186 | 0,144<br>0,21 |
| Polymer-limy paint | 0,029<br>0,032 | 0,057<br>0,064 | 0,084<br>0,094 | 0,11<br>0,123 | 0,133<br>0,151 | 0,156<br>0,177 | 0,178<br>0,202 | 0,198<br>0,226 |
| Limy paint | 0,077<br>0,022 | 0,139<br>0,044 | 0,187<br>0,064 | 0,225<br>0,083 | 0,225<br>0,101 | 0,279<br>0,117 | 0,298<br>0,133 | 0,313<br>0,147 |

Note. Above the line it is shown the values of the function, which characterizes the influence of hereditary factors on the properties of the coatings $_{o}\int^{t} V(\tau) K(t,\tau) d\tau$ during thermal ageing, below the line - in the process of moistening. For the PVAC and limy coverings value of the function describing influence of the hereditary factor on change of durability of adhesion during humidifying more than in process of thermal ageing, that, obviously, is caused by the stronger influence of a prehistory of ageing in comparison with destructive influence of temperature.

## Conclusion

The model (6) determine the properties of coatings based on hereditary factors.

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