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The Kinetics Model of Coverings' Properties with Consideration of the Heredity Factor

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Abstract

Data on the ageing model for protective –decorative coverings of external walls of buildings is given, with consideration of the heredity factor which takes into account prehistory of ageing of coverings.

Keywords: covering, ageing, heredity factor, model

Introduction

It is known, that the properties of protective - decorative coverings among other factors are determined by conditions of formation of their structure and properties. During ageing numerical values of properties of coverings at the moment of time t are determined also by kinetics of their previous change, dependent on intensity of climatic influences (intensity of UV-irradiation, temperature, humidity of air, etc.), i.e. prehistory of ageing. Thus value of properties of coverings can be presented as the expression representing the sum of convertible and irreversible processes.

Methodology

As a proof of this the received numerical values of physicomechanical properties of coverings serve during ageing. Samples of the polymer-limy coverings, the PAC coverings and coverings from dry finishing mix during influence on them of a moisture after three-day humidifying were dried up within two weeks at a temperature of air 18-20^{0}C and relative humidity of 60-70 % then the samples were tested for a stretching. In tab. 1. the data on change of physicomechanical properties of coverings is presented.

Table 1
Physicomechanical properties of coverings

The name of parameters	Before tests	After humidifying and the subsequent drying
The polyvinyl-acetate-cement (PAC) covering		
Cohesive strength, MPa	2,22	3,56
The modulus of elasticity, E 10^2, MPa	1,31	1,34
Elongation ε, %	1,76	2,87
Plastic deformation, $\varepsilon_{пл}$, %	0,1	0,13
The polymer-limy covering		
Cohesive strength, MPa	1,87	3,17
The modulus of elasticity, E 10^2, MPa	1,03	1,34
Elongation ε, %	1,00	1,6
Plastic deformation, $\varepsilon_{пл}$, %	0,5	0,26
The covering on the basis of dry finishing mixture		
Cohesive strength, MPa	1,66	2,32
The modulus of elasticity, E 10^2, MPa	1,31	1,51
Elongation ε, %	1,16	1,26
Plastic deformation, $\varepsilon_{пл}$, %	0,10	0,2

The results of experimental researches testify that drying of the PAC coverings after 3 day of humidifying promotes the further hardening of structure of the covering. So, initial value of cohesive strength: R_p = 2,22 MPa; and at the subsequent drying after humidifying: R_p = 3,56 MPa. Similar laws are also true for the polymer-limy coverings and for the coverings on the basis of dry finishing mixture. So, for coverings on the basis of dry finishing mixture, initial value of cohesive strength: R_p=1,66 MPa; and after drying: R_p = 2,32 MPa.

The received results testify that after three day of humidifying the share of destructive processes in the mechanism of ageing of coverings on a basis polymer-mineral binding is insignificant as the subsequent drying not only restores initial cohesive strength, but also promotes its increase.

With increasing in duration of humidifying there is an incomplete restoration of properties of coverings, i.e. there are irreversible phenomena. This is evidenced by data on changes in strength of adhesion for the PAC as well as polymer-limy coatings (Table 2).

Table 2
Restoration of strength of adhesion of coverings after humidifying and the subsequent drying

Kind of a covering	Adhesive strength, MPa						
	Age of tests, days						
	0	10	20	30	50	90	120
PAC	2,42	2,15 / 2,3*	1,98 / 2,2	1,75 / 1,93	1,6 / 1,86	1,4 / 1,79	1,23 / 1,6
Polymer-limy	2,2	1,9 / 2,1	1,72 / 1,9	1,5 / 1,62	1,45 / 1,56	1,2 / 1,4	1,09 / 1,15

Note.* Above the line - feature values of adhesive strength of coverings after humidifying, below the line - after drying of coverings.

Thus, the initial adhesive strength for the PAC coverings (before tests): $R_{сц}$ = 2.2 MPa; after 10 days there is an incomplete recovery of the adhesive strength, which becomes as much as 95.45% of the original after drying. Moreover, with increasing duration of humidifying, the proportion of irreversible processes increases, i.e. the adhesion strength of the covering after drying is less and less in comparison with the initial value. Thus, after 120 days of humidifying, adhesive strength of the PAC covering becomes as 66% (after drying) of the initial value. Similar patterns are typical for the polymer-limy covering.

For the mathematical description of the laws of ageing we will use the approach of the hereditary theory of ageing [1, 2]. Let's consider the change in adhesive strength of coverings over time. Let at the moment of time t_1 humidifying factor impacts on the covering. When $t > t_2$ humidifying action stops. Drying occurs as well as some recovery of adhesive strength. At time t_1, internal stresses σ_1 appear in the covering. An influence of external factors continues uninterruptedly and therefore the value at time t_2 is the sum of the internal stresses occurring. Duration of humidification is $\Delta t = t_2 - t_1$. Consider the situation that will arise through an arbitrarily small interval of time after t_2. Behavior of the covering, i.e. the numerical values of adhesive strength will depend not only on changes in the external environment, but also from the original values of the stresses σ_1.

The coverings have the property that can be called as a memory effect. The behavior of a covering depends not only on the current state of stress, but also on the all past states, i.e., the covering's material "remembers" these past states .Obviously, the numerical values of the properties of coverings will be determined by the duration gap Δt as well as the time separating the moment t from the time t_2.

In the ageing process in the time interval $t_1 < t < t_2$, a decrease of adhesion strength, characterized by a measure of $C(t)$. When $t > t_2$, there is some recovery of adhesive strength, i.e., change of adhesive strength has reversibility. We assume that at the moment of time t quality score is the sum of two terms.

$$R(t) = R(t) + \int_0^t R(\tau)K(t,\tau)d\tau \qquad (1)$$

The first item represents the instantaneous component, the second item - an inherited component. It is defined as follows. Remembering the state of the covering's properties at the time τ and $\tau + d\tau$, belonging to the past, should be proportional to the properties of the coating at time $\tau - R(\tau)$ and the duration of the interval $d\tau$. To account the prehistory of the ageing function is introduced a forgetting function $K(t,\tau)$.

If $K(t,\tau)$ tends to a finite limit $t \to \infty$ and while approaching this limit fast enough, it can be assumed that the result of previous exposure amounts to adding a decreasing component $\int_0^t R(\tau)K(t,\tau)d\tau$ and his memory is preserved forever, at the same time irreversible changes appear in the covering.

In equation (1) $R(t)$ – function characterizes the process of changing of the properties of the covering without the hereditary factor. The function $K(t,\tau)$ characterizes the hereditary material properties and is called the kernel of heredity. We represent the function $K(t,\tau)$, as a product of two functions.

$$K(t,\tau) = h(t)\varphi(t-\tau), \qquad (2)$$

Where $h(\tau)$ - function describing the ageing process of the covering.
Function $h(\tau)$ is usually approximated by the equation

$$h(\tau) = C_{\text{пр}} + C_o / \exp(-\beta\tau) \qquad (3)$$

Constant $C_{\text{пр}}$ characterizes the limit of properties of the coverings.
$\varphi(t-\tau)$ is a function, describing the effect of duration of exposure, characterizes the hereditary properties of the covering.
Function $\varphi(t)$ varies within $0 < \varphi(t) < 1$ $0 < t < \infty$
After some mathematical transformations the model of ageing of coverings can generally be approximated by the expression

$$R(t) = A\exp(-\alpha t) - \alpha\int_0^t A\exp(-\alpha\tau)\{C_{\text{пр}} + C_o / \exp(-\beta t\}(1 - \exp(-(t-\tau)))d\tau$$

Conclusions

The proposed model was tested within the analysis of ageing of the PAC coverings. The obtained results of calculation correlate well with the experimental data.

References

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