INFLUENCE OF COMPOSITION OF REPAIRING MORTARS ON ADHERENCE

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Abstract
A theoretical research on the influence of the nature and the composition of the repairing mortars has been executed in order to point out the most important parameters acting on the adherence properties.

This study is based on the theory of adherence and presents the influence of the characteristics of the mortars, related to contact angle, porosity, capillarity, hardening reactions, dimensional stability and kinetics of contacts.

Finally, fifteen parameters are described as having an important influence on the behaviour of the interface layer between concrete support and the repairing mortar.

Keywords: repairing mortar, adherence, properties, contact angles, porosity, capillarity, kinetics of contacts..

1 Introduction

The adherence between a repairing mortar and the substrate proceeds by different aspects. It is necessary to make a classification of the different factors influencing the behaviour of the interface in order to insure the performance and the durability of the joint that has been realized. Most of these considerations are based on the theory of adherence.

2 Theory of adherence

To have adhesion between two bodies, two conditions must be fullfilled :

1. there must be a molecular contact at the interface between the two bodies;
2. there must exist forces of adhesion that must act at the level of the interface and that maintain the seal during the whole service-life.

The first condition means that one of the two bodies is able to spread over the surface of the solid, in order to shift the air or other contaminants : it is thus necessary that it is a liquid phasis. The ideal liquid body (mortar, adhesive,...) must present the following characteristics :

- to be able to wet the solid body : that means that its contact angle must be equal or near to zero;
- the moistening must happen with a sufficient speed (kinetic condition);
- during the contact phenomenon, there must be an elimination of the air bubbles and the liquid body must produce the shift of the contaminant.

The second condition means that there are attractive forces between the support and the liquid body. These forces can come from different sources :

- mechanical effects : there is a mechanical inter-penetration between the support and the adhesive;
- diffusion effects : some constituants of the adhesive can diffuse into the support, so that the internal cohesion of the adhesive is partially transfered into the support;
- adsorption effects : there are intermolecular interactions between the adhesive and the support. These interactions can be : (i) secundary bonding (H-bonding, Van der Waals bondings); (ii) giving-receiving bondings; (iii) primary bondings (chemical type).

These effects are more pronounced when the surface development is larger and the contact is better. The discussion here will concern the parameters related to the nature of the repairing mortar (PCC, CC, PC).

3 Factors influencing adherence and related to repairing mortars

The factors influencing adherence are of three types :

- the support characteristics;
- the repairing mortars;
- the operating conditions.

Among the factors related to the quality of the support, we have to point out the surface energy, the rugosity, the capillarity, the dimensional stability, the mechanical resistance and the composition of the interstitial water. The influence of the characteristics of the repairing mortars is here developed.

3.1 Contact angle

The surface energy of the new layer determines its ability to wet the supporting surface. The thermodynamical conditions to have a good wetting are that the free energy W_F, related to the formation of the interface is negative. This energy is given by the following equation

$$W_F = \gamma_{as} - \gamma_a - \gamma_{sv}$$

where γ_{as} = free energy of the interface
γ_a = free energy of the new layer
γ_{sv} = free energy of the substrate.

By introducing the YOUNG relation

$$\gamma_{sv} = \gamma_{as} + \gamma_a \cos \theta_f$$

where θ_f = contact angle
and the WENTZEL relation

$$\cos \theta_f = r_f \cos \theta$$

where r_f = roughness factor, that means the ratio of the actual area to the projection area of the solid
θ = contact angle on the smooth surface

we obtain :

$$W_F = - \gamma_a (1 + r_f \cos \theta)$$

That means that the formation of the interface leads to a decrease of the free energy, except if $r_f \cos \theta < -1$. So if the wetting angle θ is between 0 and 90°, the formation of the interface is thermodynamically more stable. On the other hand, the spontaneous wetting happens only when $\theta = 0$. But the surface energy of the new layer acts also through the value of the capillarity height given by the relation

$$\ell_p = \ell \left(1 - \frac{p_a r}{2 \gamma_a \cdot \cos \theta + p_a r} \right)$$

where

l_p = penetration height
l = capillar pore length
p_a = atmospheric pressure
r = radius of the pore

We see that ℓ_p is increasing when θ decreases. The wetting power of the new layer depends on the nature of the liquid phase in which the binder is in dispersion or solution.

3.2 Attractive forces

To have adhesion we need attractive forces at the interface. The nature and the intensity of these forces are directly related to the nature of the binder and its concentration (cement, hydraulic binder, reactive resin,...).

3.3 Hardening reactions

Attractive forces between the support and the liquid body can give adherence only if the hardening of the binder is completed. The most important factor responsible of disturbances in hardening is the presence or absence of water; for CC binder, the water of the new layer can be absorbed or adsorbed by the substrate if it is not in hygrometric equilibrium with the new layer. Too much water in the substrate can also diffuse in the new layer made with PC and disturb the polymerisation.

3.4 Kinetics of contact

The contact between the substrate and the new layer needs an adapted viscosity of this new layer. It is therefore essential to work quickly because this viscosity is changing with time (hardening, evaporation of solvents,...). The WASBURN equation gives the evolution of the capillarity height with time :

$$\ell_p = \sqrt{\frac{r\gamma_a \cos\theta}{2\eta}.t}$$

where

l_p = capillarity height
γ_a = free energy of surface of the new layer.
θ = wetting angle
η = viscosity
t = time
r = radius of the pore.

We observe that this height increases when the viscosity decreases. It depends on :
- the type of binder;
- the type of solvent and its concentration;
- the temperature of the substrate and the environment;
- the time.

A high temperature would decrease the initial temperature but produces a faster evaporation of the liquid phase. It will consequently give a decrease of adhesion capacity.

3.5 Dimensional stability

An important factor of disturbance is creep : the hardening reactions of the binder and/or the evaporation of the solvents will produce creep into the new layer. The total deformation of the repairing mortar integrates :

- elastic deformation;
- deformation due to deferred rheological effects;
- deformation due to microcracks.

These creeps induce tangential stresses at the interface and the behaviour of the support will be of prime importance. Temperature and hygrometric variations can also produce dimensional variations and so tangential stresses at the interface.

3.6 Porosity

The porosity of the new layer will act seriously on the adherence property and its durability. Generally, it is admitted that the natural respiration of the substrate may not be disturbed by the application of the new layer. However, a too important porosity opens the interface to humidity agression and decreases adherence properties. The porosity can be evaluated by the capillar absorption coefficient and the water vapor transmissivity coefficient.

4 Work algorithm

The following parameters have been pointed out as influencing adherence properties of the interface :

Support parameters	
Surface energy	γ_S
Rugosity	R_1
Capillar absorption coefficient	K
Water content	E
Superficial cohesion	σ
Composition of interstitial water	I

New layer parameters	
Wetting power	S
Binder type	L
Binder concentration	CL
Hardening quality of the binder	D
Viscosity / Solvent content	CS
Stresses relaxation	R
Coefficient of thermal dilatation	α
Water vapor transmiss.coeff.	μ
Capillar absorption coefficient	A

These parameters are not independant : Particulary, we must consider :

$R = f(L, CL, R_1, \ldots)$

$\alpha = f(L, CL)$

$\mu = f(L, CL)$

$A = f(L, CL)$

Therefore, we have to take into account 11 primary parameters and 4 secundary parameters.

5 Conclusions

The choice of a good repairing mortar is not easy or simple. Many parameters are influencing this choice : the operating conditions, the operating mode, the worker qualification, the environmental interference,... have also been analysed and parameters pointed out. Many products have been used and applied in several conditions in order to verify the influence of these factors and, probably, to make a classification.

6 References

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