Fading concrete block surfaces

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Abstract: Primarily metal oxide pigments are used for the colouring of concrete. They are first-order concrete additives. They are chemically inert, do not show any chemical or physical changes during the hydration of concrete; they are weather resistant as well as resistant to light, UV light or other natural influences. Users, anyhow, complain that the colour intensity of concrete block surfaces is altering in the course of time and that, in particular, dark concrete blocks are brightening. How can this phenomenon happen?

This paper illustrates the changes that may occur in the pigments and on the surface of the concrete block in the course of time. Changes in the pigment or caused by the pigment only occur exceptionally, e.g. in case of the blue pigment ultramarine which may react in combination with cement or in case of carbon pigment, which can escape from the hardened cement paste matrix in the course of time because of an insufficient bonding stability. The metal oxide pigments used for the colouring of concrete do not show such phenomena. A brightening effect may, however, occur with such pigments too.

Brightness is due to diffuse light scattering on needles, bubbles or droplets. The light appearing on the concrete block surface leads to a certain colour impression as a consequence of partial absorption and reflection or to brightness as a consequence of diffuse scattering. Both phenomena are competing with each other. The colour impression diminishes if additional diffuse light scattering on the concrete surface results in more brightness. Additional diffuse light scattering can be caused by additional needles (efflorescence) or by a late growth of the binding agent. Mechanical abrasion of coloured cement paste may also lead to colour changes on the concrete block surface.

KEYWORDS: Pigment, metal oxide, bonding, stability, hardened cement paste, diffuse light scattering, absorption, reflection, brightening effect, efflorescence, needle growth, binding agent, cement

1. Binding stability of pigments in concrete blocks

It is recommended to use metal oxide pigments for the colouring of concrete. They feature excellent bonding characteristics in the cementitious system in terms of durability and quality. Apart from the mechanical fixation of the pigment particles in the porous structure of the C-S-H phase, which applies to all pigments, these metal oxide pigments are additionally bonded through an electrostatic fixation in the C-S-H phase. Whereas organic pigments (see Figure 1) and carbon pigments can escape from the hardened cement paste matrix, metal oxide pigments are durably bonded, as long-term weathering tests[1] reveal.



Figure 1: Outdoor weathering of concrete roof tiles coloured with various pigments

2. Generation of brightness on concrete surfaces

Despite the fact that metal oxide pigments are durably fixed in the concrete block, users complain that the surface of concrete paving blocks may show differing colour shades in the course of time. They particularly claim that dark concrete products become brighter over the years. How does this complaint correspond to the statement that pigments durably bond to the hardened cement paste matrix?

2.1. How does brightness occur?

Brightness occurs whenever light strikes on small particles, for examples, needles, droplets or bubbles, getting scattered diffusely there. Apart from that the occurrence of colour on an object is due to light, as a part of the visible light is absorbed and the remaining part is reflected. Both processes are competing with each other, because the part of the light being scattered diffusely is not available for the colouring effect. From everyday experience, we are quite familiar with this competitive situation between diffuse light scattering and colouring effect (light beer head on dark beer, for example), but also in case of concrete surfaces (increase in brightness because of a high w/c ratio, lime efflorescence on concrete surfaces).

2.2 Is the pigment a possible root cause for brightening on the concrete surfaces?

There are only few cases known where pigment loses its effect. The pigment ultramarine, a blue pigment, is not suitable for the colouring of concrete because it reacts with discoloration in conjunction with cement. Though a coating protects the pigment against the attack of cement, but long mixing times can destroy the coating, triggering the cement reaction (see Figure 2).



Figure 2: A concrete paving block coloured with Ultramarine Blue showing discolouration. On the left, short mixing time; on the right, longer mixing time and loss of colour

Carbon pigments and organic pigments can leave the hardened cement paste in the long run[2] owing to an inadequate fixation through electrostatic bonding to the cement paste, resulting in a brightening effect or loss of colour on the concrete surface.

2.3 Which other root causes for brightening on the concrete surface are known?

Directly after manufacturing there is a layer of cement paste on the surfaces of concrete paving blocks. The colour of this cement paste layer is determined by the fines content of the concrete mixture. If this upper layer is removed, either by finishing processes such as blasting, grinding or acidulating, coarser aggregates appear on the surface of the paving block[3]. The same phenomenon occurs if the upper cement paste layer disappears in the course of time owing to mechanical load. This may lead to colour changes or changes in brightness on the concrete block surface (see Figure 3).



Figure 3: Colour changes and changes in brightness on the surfaces of concrete paving blocks caused by finishing processes

The occurrence of efflorescence on the surface of the concrete paving block[4] often results in a diminished colour impression and an increase in brightness. Lime efflorescence is caused by a reaction of calcium hydroxide, which forms during the cement hydration, with the atmospheric carbon dioxide. The needles that form on the concrete surface in this process lead to additional diffuse light scattering and to brightening.

Due to the fact that the cement hydration takes not only a few weeks but several months, there is another source for an increase in diffuse light scattering. In particular cement grades containing hydraulic or pozzolanic materials (cement types

CEM II, CEM III, CEM IV and CEM V) require longer periods for the complete hydration than pure Portland cement[5]. The late growing of cement needles leads to additional diffuse light scattering, and thus to additional development of brightness.

3 Conclusion:

Concrete is a living building material. The hydration of concrete is not completely finished even several years after its production. This manifests itself visually in particular on the concrete surface. Efflorescence and abrasion may be additional sources of visual changes on concrete surfaces. Metal oxide pigments are outstandingly suitable for coloring concrete and permanently integrated into the cement matrix. They are first order concrete additives, which have no chemical reactivity in concrete. Changes in color of concrete surfaces are therefore not attributable in most cases to defects in the pigments used but are based on the described phenomena of concrete.

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