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ANALYSIS OF THE REASONS FOR THE SURFACE DEFECTS OF THE CONCRETE AND REINFORCED CONCRETE STRUCTURES, CAUSED BY THE PHYSICAL AND CHEMICAL EFFECT OF THE AGENTS ON THE CONCRETE MIXTURE AT THE INTERACTION BOARDER WITH THE MOULD

ABSTRACT

The article represents the analysis results of the main reasons for formation of the concrete products surface defects, caused by the physical and chemical interaction of the agent components and concrete at the interaction boarder with the mould, as well as describes the ways to prevent them. As a result of the performed analysis, the reasons for the defects formation of the concrete products surfaces were detected and analysed: grease stains, blowholes, concrete dyeing, loose deposit (scab), rusty stains on the surface of the finished product, destruction of the concrete surface layer of the finished product.

It was found out that the defects formation on the concrete surface of the finished product is caused by the following factors: a mismatched blend composition of the mould release agent, not considering the

technological peculiarities of the concrete product manufacturing, an insufficient or excessive agent consumption.

The article provides the practical recommendations, allowing to significantly decrease or exclude a possibility of the defects formation on the surface of the finished concrete and reinforced concrete products.

As a result of the performed studies it was found out that the consumption within 7–10 g/m^2 of the agent active material will ensure proper demoulding of the product, and at the consumption more than 20–30 g/m^2 the following can be often observed: grease stains form on the concrete surface, the colour changes, the concrete surface layer looses etc.

Dyeing of the concrete surface can be caused by the following: dyeing components in the agent; presence of the substances in the agent, capable of the physical and chemical interaction with the concrete mixture components.

In most cases the surface blowholes on the concrete are the result of the air bubbles concentration at the interaction boarder between the concrete mixture and mould release agent. The size of the bubbles depends to a certain degree on the release agent. Adding of the surface active substances to the agent composition will contribute to the bubbles split to the tiniest sizes (less than 1 mm).

The surface active substances in the agent, as well as calcium and aluminium ions in the concrete will contribute to the formation of the scab on the concrete surface. The volume of the scab decreases when adding fatty acid to the agent composition.

After stripping of the concrete and reinforced concrete products, their surfaces can be exposed to the rust stains, appeared as a result of the surface dyeing with the steel mould corrosion products. The mould corrosion can appear if the applied mould release agent does not have enough capability to protect them from corrosion under the conditions of the moulded products solidification, especially, in case of the steam treatment. In order to ensure the anticorrosion protection of the steel moulds, corrosion inhibitors are added to the agent composition.

Destruction of the finished product surface layer is caused by the physical and chemical interaction of the agent components and concrete mixture. In case of improper ratio of the agent components, the reaction

products in the form of a thin loose deposit layer can accumulate on the concrete and(or) mould surface. In case of proper ratio of the agent components, the layer of the reaction products is so thin that it cannot be seen visually.

The obtained results of the studies can be used as the basis for development of the mould release agents' formulation.

Keywords: concrete mixture, mould release agent, adhesion reduction, defects on the concrete products surface, ways to prevent possible defects.

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АНАЛИЗ ПРИЧИН ДЕФЕКТОВ ПОВЕРХНОСТИ БЕТОННЫХ И ЖЕЛЕЗОБЕТОННЫХ ИЗДЕЛИЙ, ОБУСЛОВЛЕННЫХ ФИЗИКО-ХИМИЧЕСКИМ ВОЗДЕЙСТВИЕМ СМАЗОК НА БЕТОННУЮ СМЕСЬ НА ГРАНИЦЕ ЕЕ СОПРИКОСНОВЕНИЯ С ФОРМОЙ

АННОТАЦИЯ

В статье представлены результаты анализа основных причин образования дефектов поверхности бетонных изделий, вызванных физико-химическим взаимодействием компонентов смазки и бетона на границе соприкосновения с формой, и описаны способы их предупреждения. В результате выполненного анализа выявлены и проанализированы причины возникновения дефектов бетонных поверхностей изделий: масляные пятна, раковины, окрашивание бетона, рыхлый осадок (налет), ржавые пятна на поверхности готового изделия, разрушение поверхностного слоя бетона готового изделия.

Установлено, что возникновение дефектов на поверхности бетона готового изделия обусловлено следующими факторами: неправильно подобранным компонентным составом разделительной смазки без учета технологических особенностей производства бетонных изделий, недостаточным или излишним расходом смазки.

Даны практические рекомендации, позволяющие значительно уменьшить или исключить возможность возникновения дефектов на поверхности готовых бетонных и железобетонных изделий.

В результате проведенных исследований установлено, что расход в пределах от 7 до 10 г/м^2 действующего вещества смазки обеспечивает качественное отделение изделия от формы, а при расходе более 20–30 г/м^2 на поверхности бетона часто образуются масляные пятна, наблюдается изменение цвета, разрыхление поверхностного слоя бетона и др.

Окрашивание поверхности бетона может быть вызвано следующими причинами: наличие в составе смазки окрашивающих компонентов; присутствие в ней веществ, способных вступать в физико-химическое взаимодействие с компонентами бетонной смеси.

В большинстве случаев поверхностные раковины на бетоне являются следствием концентрации воздушных пузырей на границе взаимодействия бетонной смеси и разделительной смазки. Размер пузырей в определенной степени зависит от используемой смазки. Введение в состав смазки поверхностно-активных

веществ способствует дроблению пузырей до мельчайших размеров (менее 1 мм).

Формированию налета на поверхности бетона способствуют поверхностно-активные вещества в составе смазок и ионы кальция и алюминия в составе бетона. При введении жирной кислоты в состав смазки величина налета снижается.

После распалубки бетонных и железобетонных изделий на их поверхности могут возникать ржавые пятна, которые образуются в результате окрашивания поверхности продуктами коррозии стальных форм. Коррозия форм возникает, если нанесенная разделительная смазка не обладает достаточной способностью защитить их от коррозии в условиях твердения сформованных изделий, особенно при термовлажностной обработке. Для антикоррозионной защиты стальных форм в состав смазки вводят ингибиторы коррозии.

Разрушение поверхностного слоя готового изделия обусловлено физико-химическим взаимодействием компонентов смазки и бетонной смеси. При неправильном подборе соотношения компонентов смазки продукты реакции в виде тонкого слоя рыхлого вещества способны откладываться на поверхности бетона и (или) формы. При удачном подборе соотношения компонентов смазки слой продуктов реакции настолько тонкий, что визуально незаметен.

Полученные результаты исследований можно использовать в качестве основы для разработки рецептуры разделительных смазок.

Ключевые слова: бетонная смесь, разделительная смазка, снижение адгезии, дефекты на поверхности бетонных изделий, способы предупреждения возможных дефектов.

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INTRODUCTION

A concrete mixture is a complex composition of substances with physical and chemical activity in relation to the material of the mould, contacting with it or formwork during solidification. A solidified concrete mixture is characterised by a high adhesion to the steel surface of the mould that hampers stripping of the finished concrete and reinforced concrete products. In order to reduce adhesion to the working surface of the moulds and formworks, a layer of the mould release agent is applied, which serves as a buffer, preventing the physical and chemical interaction of the concrete mixture active components with the moulds and formworks material. A proper agent can reduce the value of concrete adhesion to the moulds and formworks material almost to zero and ensure easy and quality stripping of the manufactured constructions and products.

The role of a modern mould release agent is not just to ensure the adhesion value reduction, but to participate in the formation of a high quality concrete surface. Poor or mismatched agent is the reason for the formation of multiple defects on the finished product surface, including: blowholes, grease and rust stains, scab, and destruction of the product surface layer.

Open pores on the concrete surface contribute to moisture penetration to the concrete layer during exploitation and contribute to life reduction of the structures, mould material and formwork corrosion reduce their life, grease stains and scab reduce the adhesion value of the finishing or decorative material to the surface and deteriorate the appearance of the concrete product. A poor-quality surface of the finished product requires resources and time to finish the surface of the concrete product.

In order to achieve a high quality concrete surface, the mould release agent shall have a range of the functional properties:

ensure reduction of the concrete adhesion to the moulds and formworks material;

disperse the air bubbles at the interaction boarder of the concrete mixture with the agent up to visually inconceivable sizes;

soak the surface of the moulds and formworks and be evenly distributed on it;

remain on the vertical surface of the moulds and formworks;

not have a corrosion effect on the materials of the moulds and formworks, as well as on the concrete;

maintain the functional properties in a wide temperature range.

In order to achieve a proper surface of the concrete and reinforced concrete products and constructions, a complex approach to the development of the mould release agent, not just considering the blend composition, but the technological peculiarities of the concrete mixture and agent manufacturing.

DEFECTS ON THE SURFACE OF CONCRETE PRODUCTS

A concrete mixture is a ready to use mixed homogeneous mixture of a binder, aggregates and water with or without addition of chemical and mineral additives, which, after compaction, setting and solidification, turns into concrete [1]. As a rule, a concrete mixture contains plasticizers, additives that regulate concrete solidification, antifreeze, water-repellent and others [2]. The introduced additives have a significant effect on the physical and chemical activity of the concrete mixture to the material, contacting with it.

A solidified concrete mixture is characterised by high adhesion to the mould steel surface; it has a negative impact when performing stripping of the solidified concrete products. In order to reduce the value of the concrete adhesion to the moulds and formwork material, a certain thickness agent layer is applied. The agent significantly prevents the physical and chemical interaction of the concrete mixture active components with the moulds and formworks surface that, in turn, reduces the strength of the adhesion bonds. Besides, the agent affects the formation of a high quality surface. The agent shall not leave grease stains and dye the concrete, shall not cause destruction of the concrete surface layer, corrosion of the steel surfaces, curling, flaking and surface dissolving [3].

GREASE STAINS

After stripping the finished concrete and reinforced concrete products in a number of cases there are the defects on their surface in the form of grease stains, which mostly occur on the surfaces, contacting with the horizontal sections of the moulds during manufacturing, especially close to their coupling with the vertical sections. The grease stains on the products surface, as a rule, are caused by the excess of the mould release agent on the mould surface or its separate areas. The agent excess can be caused by the following reasons:

increased amount of the agent on the mould surface, exceeding the standard value;

running of the agent from the vertical surfaces of the mould to the horizontal one;

uneven agent's distribution on the mould's surface.

Exceedance of the agent's consumption can be caused by the incorrect assessment of its properties or imperfection of the used application technology. Unevenness of the application can be specified by the technological properties of the agent, in particular, a low adhesion of the agent to the mould and formwork material. Running of the agent from the vertical sections of the mould to the horizontal one occurs both when it is excessively applied, and when the agent is insufficient to retain on the vertical surface.

As a result of the performed studies it was found out that the consumption within 7–10 g/m^2 of the agent active material will ensure proper demoulding of the product, and at the consumption over 20–30 g/m^2 the following can be often observed: grease stains form on the concrete surface, the colour changes, the concrete surface layer loses etc.Modern emulsive agents contain 20–30 % of the active component (mineral or vegetable oil and modifying additives (for example, fatty acids, surface active substances etc.)), the remaining volume is water or volatile solvent. After application of such agents on the mould (about 20–30 g/m^2), water or solvent vaporizes, and a thin layer of the active component remains on the mould surface (7–10 g/m^2).When using high viscosity oil lubricants with a significant

content of the active component (80–100 %), it is very difficult to apply a thin layer. Traditional application means, including dispersing, allow to achieve the layer of the agent, corresponding to the consumption 25–30 g/m^2 that exceeds the required agent consumption by 2–3 times and leads to its overconsumption and deterioration of the finished product surface.

Grease stains on the concrete can occur because of the uneven application of the agent, caused by the physical and chemical properties of the agent itself. In such case the applied level of the agent is split into the drops. When using such agent, a plenty of small stains appear on the concrete surface. As a result of the performed studies, we found out that the agents, containing the alcohols in their initial conditions together with mineral oils prone to drops formation on the steel moulds surface. In order to eliminate drops formation, it is necessary to transfer the alcohols into the compound ethers.

In case of an insufficient capability of the agents to retention on the vertical surface, a significant amount of the agent runs off on the horizontal surface, forming the excess, which forms grease stains on the concrete. It is possible to significantly increase adhesion of the agent to a steel mould by adding certain salts of fatty acids.

DYEING OF THE CONCRETE SURFACE

Dyeing of the concrete surface can be caused by the following components of the agent:

coloured (colouring) components;

substances, capable of the physical and chemical interaction with the concrete mixture components.

Coloured (colouring) components get into the composition of the agents when adding law quality raw materials, in particular, some waste mineral oils, containing a significant amount of the graphite particles of colloidal size, stably suspended in the volume of the agent and causing the concrete to become dark in colour.

The physical and chemical impact of the agent on the concrete can be caused by the acid nature of the agent, also if the agent contains the substances, which can be adsorbed in the upper concrete layer.

LOOSE DEPOSIT SCAB ON THE CONCRETE AND MOULDS SURFACE

A thin layer (scab) of the loose deposit can form on the surface of the moulds and the finished product. It is a product of the physical and chemical interaction of some components of the mould release agent and concrete mixture. The surface active substances from the agents and ions of certain metals, present in the concrete and contributing to the formation of relevant salts, can participate in its formation.

The studies of the carboxylic acid impact on the scab formation, formed on the concrete and steel plate, which serves as a base sheet, were performed. The composition, consisting of 60 % of the industrial oil and 40 % of the petroleum solvent was accepted as a basic one. Carboxylic acid was added to the control agent composition. When using the basic composition as the agent, an insignificant amount of the scab is formed on the surface of the concrete. When adding carboxylic acid, a quantity of the scab first decreases, then gradually increases, and after that decreases again. When using the basic composition, the scab is the product of the interaction of the concrete mixture components and unsaturated cyclic hydrocarbons contained in a small amount in the petroleum solvent. When adding a small quantity of carboxylic acid, unsaturated cyclic hydrocarbons enters into a chemical reaction with it, and the scab can hardly form. When adding carboxylic acid in the amount bigger than required to bond unsaturated cyclic hydrocarbons, scab is formed as a result of interaction of the carboxylic acid with the ions of the metals, present in the concrete mixture. As a result of such interaction, the salts of carboxylic acids are formed according to the scheme:

$$2C_nH_{2n-1}COOH + Ca(OH)_2 = (C_nH_{2n-1}COO)_2Ca + 2H_2O,$$

$$3C_nH_{2n-1}COOH + Al(OH)_3 = (C_nH_{2n-1}COO)_3Al + 3H_2O.$$

With further increase of the carboxylic acid quantity, the amount of the scab decreases. Figure 1 shows the obtained dependence.

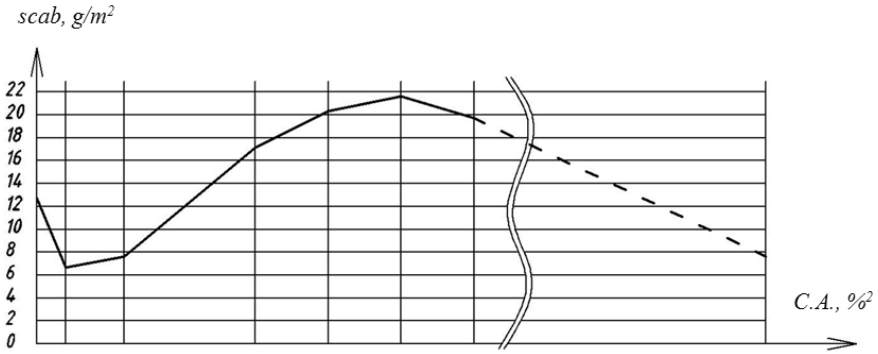


Figure 1. Dependence of the scab amount on the concrete surface on the carboxylic acid content

The loose deposits scab is formed not only on the concrete surface, but on the plate (base sheet), imitating the mould surface. Herewith, if the scab amount on the surface of the finished product decreases with the increase of the carboxylic acid content, the scab amount on the steel plate increases.

BLOWHOLES

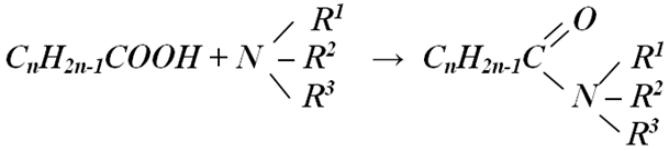
Blowholes are one of the surface defects of the reinforced concrete products after stripping. Maximum size of the blowholes on the surface of the products and constructions for A2 category of the construction concrete surface is 1 mm, and for A7 category – 20 mm [4]. In most cases the surface blowholes on the concrete are the result of the air bubbles concentration at the interaction boarder of the concrete mixture and mould release agent, as a result of the air intake out of the concrete mixture volume and outside during compaction of the concrete mixture.

The size of the bubbles depends to a certain degree on the used agent composition. If the agent contains the surface active substances, air bubbles splitting up to the tiniest sizes (less than 1 mm) is observed. As a result, giant bubbles do not form and the size of the surface blowholes is minimised and corresponds to the size of the dispersed bubbles. Therefore, the smaller the size of the air bubbles is, the smaller the surface blowholes are and the higher the surface quality of the finished product is. In case of a properly chosen

composition of the agent, the size of the surface blowholes decreases to the extent that they become visually imperceptible.

Air bubbles splitting occurs as a result of decrease of the surface tension at the interaction boarder of the air-agent phases. The surface active substances, present in the agent, are absorbed on the surface of the phases interface. As a result, the surface tension decreases, and favourable conditions for big bubbles splitting to small are created. They do not need to have their surface energy reduced by merging into coarse aggregate [5].

As a result of the performed studies it was found out that an effective decrease of the surface tension and achievement of a high degree of the air bubbles splitting requires that the mould release agent contains a combination of several surface active substances in a certain amount, among which there must be a surface active substance of the non-ionic type. Good results ensure joint introduction of the fatty acids of vegetable oils, amino alcohols and non-ionic surface active substances. In such case the fatty acids and amino alcohols, when entering into a chemical reaction, form ether-like compounds with surface active properties that can reduce the surface tension of heterogeneous systems, and non-ionic surface active substances complement the effect of the formed ethers. Interaction pattern of fatty acids and amino alcohols:



where

$R^1 = C_mH_{2m}OH$, R^2, $R^3 = H$ (option 1);
R^1, $R^2 = C_mH_{2m}OH$, $R^3 = H$ (option 2);
R^1, R^2, $R^3 = C_mH_{2m}OH$ (option 3).

The fatty acids and amino alcohols ethers also confer the anticorrosive properties to the agents in relation to other moulds and formworks details.

RUST STAINS

Sometimes after stripping of the reinforced concrete products, rust stains form on their surface as a result of the finished product surface dyeing with the corrosive products of the steel moulds. The mould corrosion can appear if the used mould release agent does not have enough capability to protect them from corrosion under the conditions of the moulded products solidification, especially, in case of the thermal and moisture treatment. In order to ensure anticorrosion protection of the steel moulds, corrosion inhibitors shall be added to the agent composition. According to the studies' results it was found out that amino alcohols, amines, fatty acids of vegetable oils, amides, phospholipids, and some nitro compounds, present in the agents, have an inhibitory effect.

The abovementioned chemical compounds confer the anticorrosive properties not only to the mineral and vegetable oils, but to the agents with a more complicated composition, containing various solvents.

DESTRUCTION OF THE CONCRETE SURFACE LAYER

Destruction of the concrete surface layer with the mould release agent is caused by the physical and chemical interaction of the agent components and concrete mixture. One of the main agent component - mineral oil – is characterised by a chemical inertness in relation to the concrete mixture and does not cause destruction of the concrete surface layer. Modern agents mostly contain a number of other substances, capable of the chemical interaction with the ions of the metals, present in the concrete mixture. Such components include fatty acids, some SAS and amino alcohols. During the concrete mixture solidification (especially at the steam treatment), the mentioned components enter into a chemical interaction with the concrete mixture, and in case of poor or improper selection of the agent components ratio, the reaction products in the form of a thin loose deposit layer is deposited on the surface of the finished product and mould. In case of proper ratio of the agent components, the layer of the reaction products is so thin that it cannot be seen visually.

CONCLUSION

Concrete mixtures and mould release agents are not inert compositions and are capable of physical and chemical interaction with each other and with other materials. In case the mould release agent lacks required technological properties, its interaction with the concrete mixture can be accompanied by formation of the following defects on the surface of the finished concrete products:

grease stains and dyeing of the finished product surface;

a decrease in the strength of the concrete surface layer and, as a consequence, formation of the blowholes of various sizes, tears and chips;

corrosion and destruction of the moulds and formworks surface, herewith the corrosion products will be transferred to the concrete surface in the form of rust stains.

The reasons for defects formation on the surface of the concrete and reinforced concrete products after their stripping, were determined, including:

The excess of the mould release agent on the moulds and formworks surface or separate areas is the main reason for formation of grease stains on the products surface. The studies' results showed that the agent amount, sufficient for a proper –mould release, varies within 7–10 g/m^2 based on the content of the active component. The excess of the agent on the horizontal surfaces of the moulds can be caused by a low capability of the agent to retain on the vertical surfaces due to its low adhesion to the mould material, as well as by an insufficient capability of the agent to soaking. As a rule, such defect is typical for the agents, containing free alcohols and mineral oils. In order to eliminate such a defect, it is necessary to transfer the alcohols to a bond state;

dyeing of the concrete surface with the components, present in the agent or formed as a result of the physical and chemical interaction of the agent components with the concrete mixture components. Presence of the dyeing colour compound in the agent is caused by the use of law quality raw materials (for example, waste oils). Capability of the agent to enter into the physical and chemical interaction with the components of the concrete mixture is caused by the substances

in its composition, which can be adsorbed in the concrete surface layer, giving it a different colour shade;

formation of a loose layer (scab) on the surface of the finished concrete products happens at the solidification stage of the concrete mixture as a result of its physical and chemical interaction with the surface active substances, present in the mould release agent. In case fatty acids are present in the agent, scab will contain the metal salts of fatty acids. When adding the compounds with an amino group or nitro group to the agents, the scab composition will become more complicated;

concentration of the air bubbles at the interaction boarder of the concrete mixture with the layer of the mould release agent, applied on the mould surface, will contribute to formation of the blowholes on the concrete surface. The size of the air bubbles, defining the size of the blowholes, depends largely on the properties of the release agent. If the agent contains certain surface active substances, the bubbles are dispersed and big blowholes are not formed on the concrete products surface;

the most common reason for formation of rust stains on the structures surface is the transition into concrete mixture at the solidification stage of the steel moulds corrosion products. The anticorrosive properties of the agents are formed when amino alcohols, amines, fatty acids of vegetable oils, some inorganic and organic nitro compounds, and phosphates are introduced into their composition;

a decrease in the strength of the concrete surface layer and its destruction cause certain modifying additives in the composition of the release agent, which can enter into chemical interaction with the components of the concrete mixture. In order to exclude such an effect on the surface of structures, the composition of the agent should be designed so that the modifying additives enter into a chemical reaction with each other during the synthesis.

To obtain a high-quality surface of concrete products and structures, an integrated approach is required not only taking into account the component composition of the concrete mixture and agent, but also the technological features of the manufacturing of concrete products.

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