USE OF CHEMICAL ADDITIVES TO IMPROVE THE PROPERTIES OF CONCRETE MIXTURES IN THE CONSTRUCTION OF CRITICAL INFRASTRUCTURE

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Abstract: *Optimizing the properties of the concrete mixture and the finished concrete is a task that has been on the agenda ever since the discovery of this popular building material. Different substances and mixtures are developed and improved, so-called additives to concrete that give it greater strength, better plasticity or adjust the setting times. These additives are thoroughly researched in construction laboratories, and their properties and effects are analyzed in various practical directions. The article presents the main principle of action of the main chemical additives used at the moment, the mode of action and the methods of their testing.*

Keywords: *chemical additives, concrete, testing*

Introduction

Chemical additives are the ingredients in concrete, different from Portland cement, water, and inert materials, which are added to the mixtures immediately before or during mixing. Manufacturers use additives primarily to reduce the costs of concrete construction, to change the properties of hardened concrete, to ensure the quality of the concrete during mixing, transporting, laying, and hardening, and to overcome certain emergency situations during specific operations.

The successful use of additives depends on the use of appropriate dosing and concreting methods. Most additives are delivered in ready-to-use liquid form and are added to the concrete at the concrete node or on the construction site.

Some admixtures, such as pigments, expansive agents, and pumping aids, are used only in exceptionally small amounts and are usually manually dosed from pre-measured containers.

The effectiveness of the additive depends on several factors: the type and amount of cement, the water content, the mixing time, the temperatures of the concrete and air.

It is possible for effects similar to those achieved by adding additives to be achieved by changing the concrete mix - reducing the water-cement ratio, adding extra cement, using a different type of cement, or changing the inert material, as well as its gradation.

I. BASIC PRINCIPLE OF ACTION OF ADDITIVES

Chemical additives are substances dissolved in water. They are added and mixed with the concrete and as a result of the physical and/or chemical action, they change the properties of fresh or hardened concrete - its workability, initial set, hardening, or

durability. The quantity of the additive is determined in relation to the weight of the cement and is within the limits of 0.2 to 2.0 wt%. When using several additives together, their effect can either be suppressed or enhanced. This should be clarified beforehand with the suppliers [2]. The main properties of the chemical additives are presented in Table 1.

Table 1

Add-on type	Meaning	Basic properties
Liquefaction agents	FM	Reducing the amount of water needed for concrete and/or improving workability.
Retarders	VZ	Postponement of the initial setting time of the concrete, e.g. during multi-stage laying, and also at high temperatures.
Air entraining	LP	Increasing freeze-thaw resistance with salts by entraining evenly distributed small air pores
Curing accelerator	HBE	Acceleration of initial strength with or without effect on initial setting time. It is used in concreting during the winter season.
Initial connection accelerator	SBE	Acceleration of initial setting time of concrete.
Stabilizer	ST	Increasing the internal cohesion of fresh concrete.
Plasticizer	BV	The amount of water required for the concrete is reduced and thus its workability is improved, i.e. it is possible to increase the strength by lowering the amount of water for the same amount of cement.
Sealants	DM	They are used in underground, hydraulic construction and in the construction of storage facilities. They reduce water absorption as well as water penetration into the concrete.
Injectable Additives	EH	They improve the fluidity, reduce the required water as well as the sedimentation and contribute to achieving a moderate swelling of the solution.

II. TYPES OF CHEMICAL ADDITIVES

The main classes of chemical additives aim to entrain air, reduce water content, retard or accelerate the process, or act as plasticizers (superplasticizers).

All other varieties of additives fall into a special category, whose functions include corrosion inhibition, shrinkage reduction, reduction of alkali-silica reactivity, improvement of workability, bonding, waterproofing, and coloring.

Air-entraining additives, which are used to create microscopic air bubbles in the concrete, are discussed in more detail in Air-Entrained Concrete.

- *Water-reducing additives*

Water-reducing additives typically reduce the necessary water content for a concrete mix by about 5 to 10%. This means that concrete treated with such an additive, compared to untreated concrete, requires less water to reach the necessary set. Treated concrete can have a lower water-cement ratio. This usually indicates that stronger concrete can be produced without increasing the amount of cement. Recent advancements in mixing technology have led to the development of mid-range water reducers. These additives reduce the water content by at least 8% and are more stable in a broader temperature range. Mid-range water reducers provide consistent hardening time compared to standard water reducers.

- *Retarding additives*

This type of additive is used to counteract the accelerating effect of high temperatures during the summer season on concrete hardening. These temperatures often cause an increased rate of hardening, making its placement and finishing processes challenging. Retarders keep the concrete workable during its placement and delay its initial set (Fig. 1). Most retarders also function as water reducers and can trap a little air in the concrete.

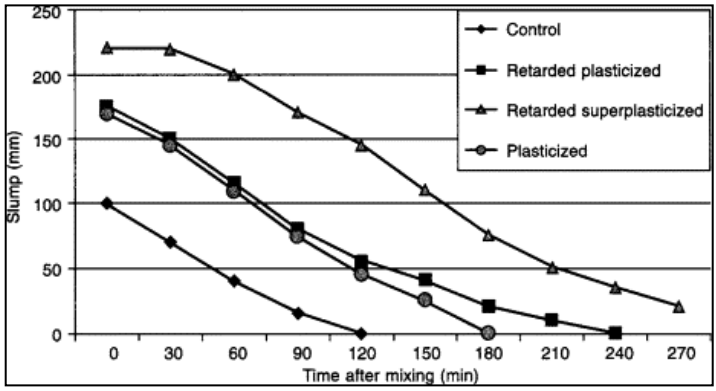

Fig. 1. Extending the time for laying the concrete. [3]

- *Accelerator supplements*

Accelerating additives are added to the concrete with the aim of reducing the binding time and accelerating the process of gaining early strength in the concrete (Fig. 2). The typical application of accelerating additives is in very low ambient temperatures, when there is a risk of water in the mixture freezing before normal cement hydration has taken place. The main advantages of using this type of additive are reducing the segregation of cement milk, the possibility for early formwork removal, improving the resistance of the new construction to freezing and thawing. In certain cases, with accelerating additives, it also achieves the possibility for earlier use of the structure.

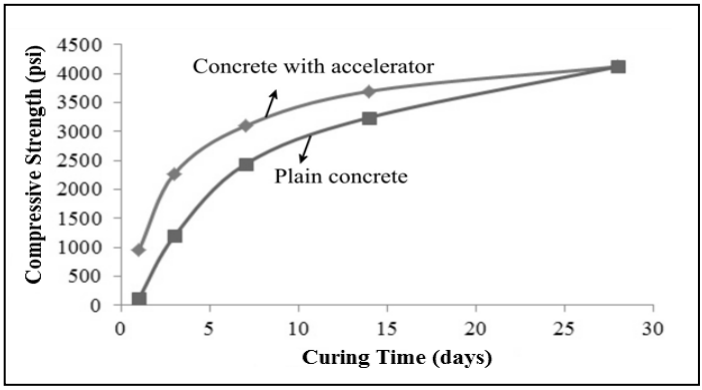

Fig. 2. Influence of the accelerating additive on the properties of concrete. [3]

Accelerators do not act as antifreeze additives, so measures should be taken to protect the concrete in the early stage when negative temperatures are expected for the period after placement.

Calcium chloride is considered the most effective accelerating additive, but its use is limited due to the potential for active corrosion in the reinforcement. Non-chloride accelerators include additives containing formic acid salts, nitrates, nitrides, and thiocyanates [4].

- *Superplasticizers*

Superplasticizers, also known as plasticizers or high-range water reducers (HRWR), reduce water content by 12 to 30% and can be added to low-to-normal slump and water-cement ratio concrete to produce flowing concrete with high workability (Fig. 3).

Flowing concrete /with high fluidity/ is workable concrete that can be placed using minimal vibration or no vibration or compaction.

The effect of superplasticizers lasts from 30 to 60 minutes depending on their brand and dosage, and is followed by a rapid loss of workability. Due to the loss of slump, superplasticizers are usually added to the concrete at the construction site.

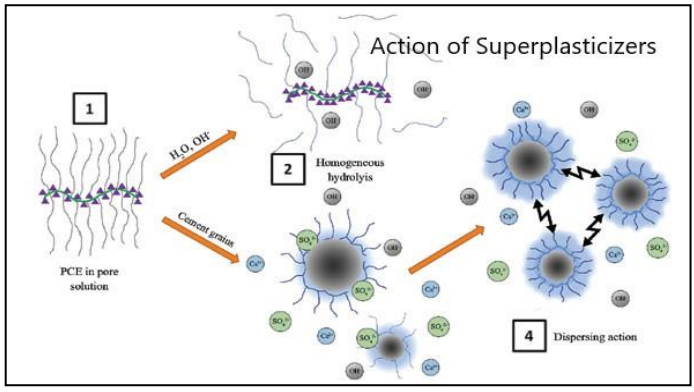

Fig. 3. Principle of the action of superplasticizer [5]

- *Corrosion inhibiting additives*

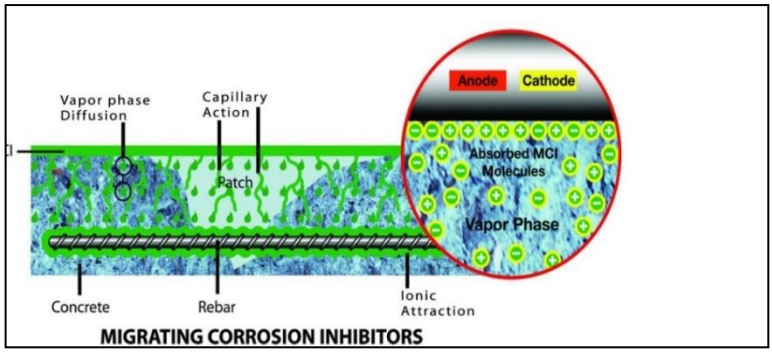

Fig. 4. Principle of action of a corrosion inhibiting additive [6]

Corrosion inhibiting additives fall into the category of special additives and are used to delay corrosion of reinforcing steel in concrete. Corrosion inhibitors can be

used as a protective strategy for concrete structures, marine facilities, highway bridges, and parking lots that will be exposed to the impact of high concentrations of chloride (Fig. 4). Other special additives are those for reducing shrinkage and inhibitors of alkali-silica reactivity. Shrinkage reducers are used to control shrinkage during drying and minimize cracking, while ASR inhibitors control durability problems associated with alkali-silica reactivity.

- *Air-entraining additives*

Air-entraining additives assist in forming small enclosed air bubbles within the volume of the concrete (Fig. 5). This reduces damage when it is exposed to freeze-thaw cycles. The additives also improve workability, mix homogeneity, guarantee reduced delamination, and prevent the exudation of cement milk on the surface. The main difference when using such additives is that the air in the concrete forms small enclosed pores (from 10 to 1000 microns), not large air gaps. The additive can be liquid or in powder form, which is mixed with the cement. Some of the most popular air-entraining additives are salts of higher fatty acids, obtained during the processing of petroleum, and compounds based on plant resins. The degree of air entrainment and the efficiency of the additive depend on the concrete recipe and the mixing conditions. It has been proven that in mixtures with a strong basic character, better air entrainment is realized, compared to those with a lower pH. The sand particle size also has an impact - the larger the particles, the more difficult the air entrainment.

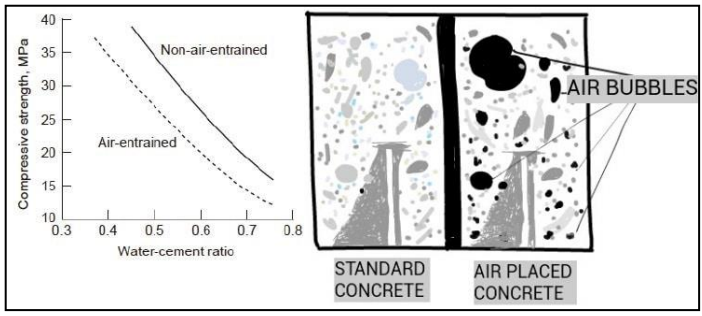

Fig. 5. Principle of operation of air-entraining additives [7]

The addition of calcium chloride typically increases the air in the mix. Some superplasticizers interact with the cement and air-entraining additives. The result is a reduction of the specific surfaces of the closed pores in the volume and an increase in the distances between them.

Concrete mixes, which include mineral additives - fly ash, may need a larger amount of air-entraining additive to achieve the same air content in the mix.

Air entrainment is inversely proportional to temperature - when the temperature rises, the volume of air introduced into the mix decreases.

Air-entraining additives are recommended for use in structures exposed to freeze-thaw cycles, the action of deicing salts, or sulfate attack.

The additives are compatible with most types of other additives.

III. FEATURES OF THE TECHNICAL DOCUMENTATION

Chemical additives for concrete must comply with standard EN BDS 934 (Fig. 6). The standard describes the most common requirements, additional requirements, properties, as well as the testing method - Fig. 6 [4].

Свойство	Метод за изпитване	Изисквания
Хомогенност	Визуално	Хомогенност при използване. Разслояването не трябва да превишава границите, дадени от производителя
Цвят	Визуално	Равномерен и еднакъв с описанието, направено от производителя
Ефективен компонент	EN 480-6	Инфрачервеният спектър да не показва изменение по отношение на ефективния компонент при сравняване с еталонен образец, осигурен от производителя
Относителна плътност	ISO 758	D ± 0,03 при D > 1,10 D ± 0,02 при D ≤ 1,10, където D е стойност, дадена от производителя

Fig. 6. Excerpt from BDS EN 934.

Указания за обработка	
Centrament N7W може да се използва с всички стандартни типове цимент. Препоръчва се употребата на портланцимент. Centrament N7W се добавя в направната вода. При температури под 0^0C се препоръчва използването на минимално количество направна вода. Не трябва да се използва ако е замръзнал. Пресният бетон трябва да бъде предпазен от загуба на топлина по време на хидратацията, особено при използване за тънки стени. Добавянето на Centrament N7W трябва да става по време на смесването на всички материали с подходящи устройства. Най- ефективен е при добавяне след първоначалната вода. Възможно е използването му и с добавената вода. Centrament N7W може да се използва като ускорител и при положителни температури. В тези случаи е добре да се използва в комбинация с MC-Schnell OC Pulver .	Centrament N7W може да се използва в комбинация с други добавки на MC-Bauchemie. Предписаното време за смесване както и съответните разпоредби за производство, обработване и допълнителна обработка на бетон със забавено втвърдяване, предварително напрегнат бетон и т.н. трябва да се спазват. Моля съблюдавайте „Общи указания за приложение на добавки за бетон". Препоръчителна дозировка: - при темп ≥ -5^0C прибл. 0.5-1% от циментовото тегло - при темп между -5^0C и -10^0C прибл. 1.5-2% от циментовото тегло

Fig. 7. Part of the technical card for Centrement N7W accelerator [8]

Another important condition when using chemical additives is to comply with the product's technical card, which describes the dosage, mixing method, and basic operations. A part of the technical card for the Centrement N7W hardening accelerator is shown in Fig. 7.

Conclusions

Chemical additives, as one of the simplest and most accessible technological methods for improving the properties of concrete, can significantly reduce unit production costs, improve the quality and efficiency of a wide range of reinforced concrete structures, increase the service life of structures, buildings, and facilities as a whole. That's why the use of chemical additives in concrete technology is given a lot of attention in global practice. For example, by the end of the 90s, the share of concrete with additives for various purposes in Japan was over 80%, in the USA, Germany, France, and Italy - more than 70%.

Additives are chemical substances (reagents) with organic and inorganic structure, complex or simple composition. They are introduced into the concrete, usually mixed with the water, and can be in liquid, solid, or paste form.

The purpose of additives is very diverse. The number that found application in the production of horosan, concrete and reinforced concrete structures is more than 300 items. About 1000 types of additives are in the stage of research and industrial testing.

On the other hand, the need to search for new additives is determined by the selective nature of their modifying effect, which depends not only on the chemical composition of the additives, but also on the chemical and mineralogical composition of the cement, the fineness of its grinding, the presence, and the amount of alkali in the cement composition.

The degree of the modifying effect of many additives also depends on the specific consumption of cement in the concrete mix, the content and type of mineral additives, the water-cement ratio, and the heat treatment regimes of reinforced concrete structures.

Thus, the choice of additives to improve the properties of concrete and the technology of production of reinforced concrete structures is not an easy task.

Therefore, for the correct choice of additives in relation to specific production conditions, the purpose of the products and the set goals, it is necessary to have a clear understanding of the classification of additives according to their purpose and the mechanism of their action.

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