

Effective shrinkage compensating admixture for joint-less fiber-reinforced concrete industrial floorings

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Abstract: The shrinkage is an inherent characteristic of Portland cement concretes, leading to their volume changes, which potentially create preconditions for the development of different types of cracking - prerequisites for integral decreasing of their durability. The elimination of the negative processes from the development of shrinkage in all its varieties (autogenous, plastic, thermal and carbonization) is based on optimization of complex mix design and technological factors, including the use of innovative chemical products - mainly minimizing and/or compensating the volume changes during setting and hardening of the concrete.

In recent years, new innovative products have entered the world and Bulgarian practice aimed to compensate the shrinkage by initiating of specific additional hydration interactions. These processes give some attractive possibilities for manageable early age increasing of the concrete volume, leading to partial or complete compensation of the negative effect of later shrinkage.

The report presents full-range complex results for the effective action of a special shrinkage compensating modifier ShCA KEPTONITE on the strength-deformation characteristics of fiber-reinforced concrete for advanced joint-less industrial flooring systems with different purposes, especially for heavy loaded logistic bases.

It is concluded that ShCA KEPTONITE demonstrates very good performance in direction to strongly minimize the final shrinkage of the concrete tested. The different dosage rate of the product is an optimal for Bulgarian cement used for testing.

Keywords: JOINT-LESS CONCRETE FLOORINGS, CONCRETE DRYING SHRINKAGE, SHRINKAGE COMPENSATING ADMIXTURE, CONCRETE COMPRESSIVE STRENGTH

1. Introduction

The industrial concrete internal floorings and external pavements are specific building constructions with constantly increasing importance for industrial practice in all over the world.

The fact that they are not defined separately as in the current Eurocode 2 [1] contributes to the existing relative ambiguity in the definition and in the methods of construction and static calculation of industrial concrete floorings/pavements. In this sense, and in the aspect of the present exposition, is the definition proposed by the author below for INDUSTRIAL CONCRETE FLOOR is: cast-in-place reinforced or non-reinforced concrete structure with geometric dimensions in plan many times exceeding the size in height, designed as a ground supported slab and surface executed by step-by-steps power floating processes, for long-term bearing of specific types of operating loads with ensured full-range resistance to environmental and production factors [2].

Regarding the design and implementation of fiber-reinforced internal industrial concrete floorings, there is essentially a lack of an unambiguously formulated normative base, both in Bulgaria, Europe and the world as a whole.

In America, the specialized documents of the American Concrete Institute (ACI), American Highway Association (AHTA), US Army Corps of Engineers, Association of Concrete Industrial Flooring Contractors (ACIFC), Contract Flooring Association (CFA), etc. are used with authority.

In Europe, apart from the partially applicable Eurocode 2, with recognized significance and practical usability are the principles laid down in the relevant Technical Report No34, 3-rd (2003) and 4-th (2013) Edition, "Concrete Industrial Ground Floor, A Guide to Design and Construction", The Concrete Society [3,4], etc. In essence, these documents are the most widely used in Bulgarian production practice related to the design and implementation of industrial concrete floors.

The Bulgarian regulatory framework, based on relevant BDS EN standards, covers fragmentarily separate parts of the "puzzle", called industrial concrete floorings/pavements.

For example, there are relevant standards for determining the strength-deformation characteristics of the slab-base, for concrete as the main construction material, for the different types of fibers (in the context of their material characteristics - geometric dimensions, material qualities, etc., as well as their relationships under bending loads), for serviceability as the main characteristic of the finish surface, for the qualities of powdered surface hardeners and some impregnating systems.

However, regulations related to construction and calculation for different loads and operating conditions, evaluation of the effective action of different types of joints, typical details, design of the concrete composition (to the extent that a number of additional requirements are imposed on it), the specific action of protective coatings, deep crystallizing and shrinkage compensating concrete systems, limits of flatness and levelness, planned service life, specified technological methods of implementation and control, repair works are completely missing, maintenance during operation, warranty conditions, etc.

The above brings a lot of confusions to the system and the relationship between the contracting authority - designer, controlling body and the contractor. Moreover, the lack of a comprehensive regulation essentially does not provide an opportunity for an unambiguous formulation of a correspondingly adequate technical assignment, which directly has a negative impact on the communication between the participants in the investment process.

2. Concrete floorings types

In modern practice, two major structural types of concrete floorings are currently specified - from the so-called "jointed" to "joint-less" types.

In classical "jointed" floorings, in addition to the necessary expansion, working and insulation joints, within the day-casting field (limited by working and/or expansion joints), are constructed and executed over a certain distance, the so-called "saw-cut" joints in depth of 1/3 of the cross-section thickness. The dimensions of the fields limited by the all type of joints are subject to calculation procedures. In general, they depend on the type and quality of the compacted slab-base, the type of loads, the concrete cross-section thickness, the characteristics of the concrete and the reinforcement systems used. In this type of flooring, a critical factor is the presence of a large total length of cut joints - for example, within a

single field of dimensions 30x30 m, limited by dilation profiles, with a grid of apparent joints 6x6 m, the total length of these joints is of the order of more than 300 linear meters.

This construction flooring type in itself has the potential for operational efficiency, but in certain conditions they prove to be problematic - above all, in intensive traffic from mobile cargo with rigid tires and in conditions of aggressive impacts. Moreover, the prerequisites for breaking and compromising the performed saw-cut joints can create insurmountable technological problems in the operation of the electronics of the used manipulators-high lifters in the presence of high racks systems. In addition, the saw-cut joints, although technologically processed, interrupt the surface uniformity and create prerequisites for breaking the impermeability of the concrete section.

In this sense, the jointed type of flooring is generally defined as a lower technological level of performance and operation, usually when looking for a "budget" type of execution.

All that logically leads to the idea of eliminating saw-cut joints, seeking to maximize the continuity of the structural fields within the floorings. This idea has recently been implemented very successfully in world practice through the implementation of "joint-less" floorings [5,6].

In terms of construction, this type of steel fibre-reinforced concrete floorings can limit relatively large single one-day casting fields with a configuration close to the square (at a side ratio of up to 1:1.5), with areas of the order of 1000-2000 m² and more. The individual fields are limited by special dilatation industrially ready-made profiles (with a corresponding doweling system), pre-installed in plan and level, which also play the role of working joints. With the highest degree of innovation and optimal operational performance are the so-called sinusoidal and cosinusoidal joints, providing a maximum high coefficient of transfer of moving loads, durability, gentle mode of wear of moving traffic, combined with comfort of operation. This type of joints, in addition to the necessary transfer of the load when moving from one field to another, ensures smooth horizontal movement in parallel with the development of the free deformations of the concrete during hydration, hardening and temperature changes – **Fig. 1 and 2**.



Fig. 1 HCJ Cosinus Slide Joint



Fig. 2 HCJ Cosinus Slide Joint with T-crossing detail

No saw-cut joints are subsequently performed within the individual field. In this way, monolithic and continuity of the surface is ensured, which is a guarantee for future trouble-free operation

On the other hand, it should be taken into account that with joint-less systems, the requirement to minimize size and volume of free deformations (mainly concrete shrinkage in all 4 basic forms) is of key importance - especially considering the formation of significant areas with not always correct geometry, limited only by expansion profiles.

3. Innovative joint-less fiber-reinforced industrial concrete floorings

The existing possibilities for obtaining high-tech fiber-reinforced concretes joint-less floorings mainly is based on the

possibilities for overcoming of all negative problems, caused by the concrete shrinkage as its internal irrevocable characteristic.

The concretes shrinkage is their inherent characteristic, leading to volumetric changes that potentially create prerequisites for the development of cracking and an integral reduction in the durability of built structures and facilities. The elimination of the negative consequences of the development of this problem in all its varieties (autogenous, plastic, temperature-humidity and carbonization) is based on the optimization of complexes of recipe-technological factors, including the use of innovative chemical products - mainly minimizing and/or compensating the shrinkage volume changes.

In recent years, new innovative products have entered global and Bulgarian practice aimed at shrinkage compensating by specific chemical processes of an initial manageable volume increase, leading to partial or complete compensation of the negative effect of shrinkage. Unlike known types of shrinkage-compensating special cements, these innovative chemical agents have not yet been standardized, despite their presence in the product range of various manufacturers.

As a result of our research, original scientific results have been obtained, confirming the effectiveness of the use of special shrinkage-compensating modifier ShCA KEPTONITE for ordinary concretes, specified as an expanding agent by the so-called type G, in accordance with the definitions of ACI Technical Report 223-10 "Standard Practice for Use of Shrinkage-Compensated Concrete" [7], for the use of which BULGARIAN TECHNICAL APPROVAL (BTO) № 0192/01.03.2021 was issued [8].

ShCA KEPTONITE is obtained after firing at a special temperature regime of a specific type of CaO (originating in South America), as a result of which, in the process of concrete hydration, portlandite Ca(OH)_2 is formed with an active expanding effect in the first 24-48 hours from the start of the process – **Fig. 3 and 4**.

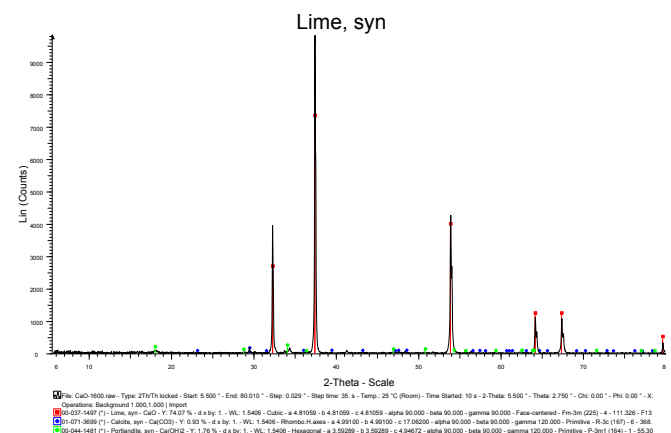


Fig. 3 ShCA KEPTONITE X-ray analysis

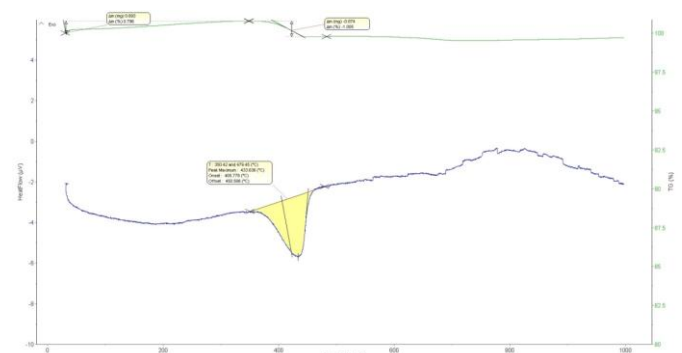


Fig. 4 ShCA KEPTONITE DTA analysis

ShCA KEPTONITE is an innovative product capable of counteracting the natural shrinkage processes of cement composites, reducing their micro-porosity and causing a compacting effect. Its specific action compensates for volume changes, and, in special cases, it can completely overcome it to a degree of controlled self-stressing. In this way, when designing the composition of the concrete, a certain controlled level of expansion can be achieved, by which the physico-mechanical properties of the concrete, as well as its corrosion resistance, can be increased. Depending on the dosage, the product has a direct positive effect on the characteristics, both at the level of the fresh concrete and also of the hardened composite. After homogenization in the composition of the concrete, the product directly affects the ongoing hydration processes by causing volume expansion, which counteracts the drying processes in its various phases. In this way, the intermolecular structural parameters are increased, which in turn increases the physical-mechanical and structural characteristics of hardened concrete, increasing its corrosion resistance under aggressive impact.

ShCA KEPTONITE is a hydration activator for professional use in cement concrete and mortar compositions, increasing their physical-mechanical and structural characteristics and compensating for their inherent volumetric drying. In this way, cement composites with its participation have fully compensated shrinkage, eliminated cracking and minimized porosity

ShCA KEPTONITE is dosed within 5-20 kg/m³ depending on the set design expansion levels. When using cement-replacement materials (eg. fly ash), their participation should be considered based on their hydraulic activity. The expansion and compaction action is intensified at a lower water-cement ratio and increased cement content.

There are original studies of ours [9-11] directed to the specific application of this product related to different efficiency of shrinkage compensation, in function of the type of cement used and the quantitative participation of the expanding agent.

Table 1: Concrete compressive strength

ShCA KEPTONITE, kg/m ³	CEMENT CEM I 52,5R HOLCIM BG plant	
	Compressive strength (MPa) at	
	7 days	28 days
0,00	24,80	36,20
12,00	26,30	39,40
15,00	27,80	40,30
18,00	28,60	42,40

The concrete mixture for the various compositions tested was manufactured under laboratory conditions by mechanical homogenization. The samples (cubes 10x10x10 cm) and prisms (beams) (10x10x40 cm) are cured in lab-condition until the day of testing. The compressive strength was determined at 7- and 28 days of age (**Table 1**), and the change in linear dimensions (free deformations) of the beams - every day up to 30 days by using special strain gauge device with accuracy of 0,001 mm (**Fig. 5 and 6**).



Fig. 5 Concrete test specimens prepared



Fig. 6 Shrinkage strain gauge device

Below is presented the kinetics of expansion/shrinkage processes as a function of quantitative participation of ShCA KEPTONITE (Reference concrete mix design based on CEM I 52,5 R, HOLCIM cement plant, Bulgaria) - **Fig. 7**.

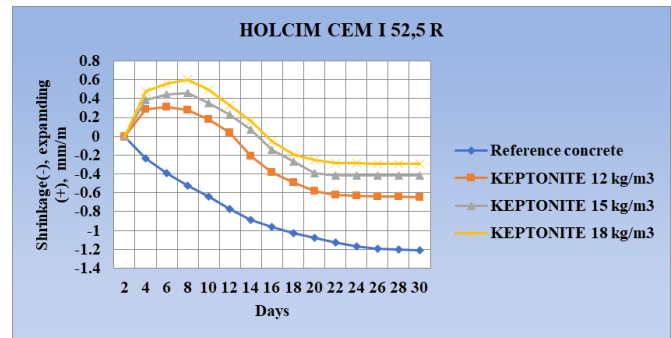


Fig. 7 Kinetics of expansion/shrinkage processes as a function of quantitative participation of ShCA KEPTONITE

The results visualizations give enough possibilities to perform reasonable analysis in direction to make respective conclusions about ShCA KEPTONITE efficiency to minimize concrete free deformations.

In **Table 2** concrete free deformations (expanding "+" and shrinkage "-") are presented as their maximal value in parallel of the age of appearances. This approach is practically usable to gaining an idea of ShCA KEPTONITE (in different dosage rates) efficiency compared to different type of cement involved in testing program.

Table 2: Shrinkage/expanding kinetics of the concrete with HOLCIM CEM I 52,5R

ShCA KEPTONITE, kg/m ³	CEM I 52,5R HOLCIM	
	Concrete free deformations (expanding "+" and shrinkage "-") up to 30 days of age	
	max "+" (at days)	max "-" (at 30-th day)
0,00	-	-1,210
12,00	0,31 (6)	-0,645
15,00	0,46 (8)	-0,418
18,00	0,60 (8)	-0,289

4. Discussion

The results obtained provide an opportunity for a comprehensive analysis of the behavior of the tested concrete in function of the dosage of ShCA KEPTONITE.

The results obtained for the compressive strength of 7- and 28-days of reference concretes (excluding ShCA KEPTONITE) are within the expected range. They are strongly influenced by the type of cement, and as a whole - the investigated concrete with cement CEM 52,5 Type I shows higher strengths. In addition, it can be confidently predicted that ShCA KEPTONITE (regardless of dosage) has virtually no significant effect on the compressive strength of the test ages, regardless of the type of cement in the concrete.

In this sense, the design of the concrete composition with the participation of ShCA KEPTONITE should be approached in a conventional manner without expecting the effect of this admixture on the mechanical characteristics of the concrete.

Discussion is possible in several different aspects regarding the linear expansion (expanding/ shrinkage) of the tested concrete with different dosage rates of ShCA KEPTONITE.

As an initial conclusion, with respect to reference concretes, it can be noted that HOLCIM cement- based concrete have the highest absolute shrinkage rate - of the order of 1,210 mm/m. For the other types of concrete, this size could be reduced by in range of about 40%.

It is also apparent significant influence of this admixture dosage rate, regardless of the type of the cement in the composition of the test concretes. For different types of cements, different dosages practically greatly reduce the final shrinkage time of 30 days. The

effect of ShCA KEPTONITE on HOLSIM-based concrete is particularly emphasized - the maximum dosage reduces about 3,5 times the nominal final drying shrinkage.

Of interest is the analysis of the absolute value of the initial expanding as a function of the dosage of the admixture used. It is evident that the HOLCIM cement-based concrete shows the highest expanding values at different dosages of the ShCA KEPTONITE. This occurs at 6-8 days of age after process monitoring.

Of interest is the analysis of the absolute value of the initial expanding as a function of the dosage of the admixture relative to the different types of cements used in the test compositions. It is evident that the HOLCIM cement-based concrete shows the highest expanding values at different dosages of the ShCA KEPTONITE. This occurs at 6-8 days of age after process monitoring.

Most categorical is the effect of this admixture in HOLSIM cement-based concrete - the dosage of 18 kg/m³ reduces about 2,2 times the final shrinkage, compared to that of concrete with 12 kg/m³ ShCA KEPTONITE.

At the moment, this original product is widely used in the innovative practice for the design and implementation of joint-less industrial concrete floorings with large one-day fields (of the order of more than 2000 m²), limited by expansion joints - **Photos 8 -13**.

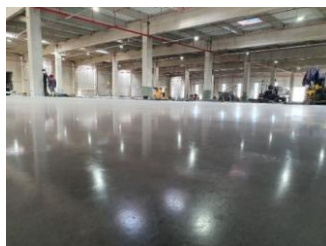


Fig. 8



Fig. 9



Fig.10



Fig. 11

Fig. 8-11 Joint-less fiber-reinforced concrete floorings

5. Conclusions

The original scientific results obtained from the study make it possible to evaluate the application of ShCA KEPTONITE as particularly effective in reducing drying shrinkage of fiber-reinforced concrete produced on the basis of one of various typical for Bulgaria cement - HOLCIM CEM I 52,5 R. It could be expected that the different type cements would be predetermined the different kinetics of free deformation, which, obviously, was provoked primarily by the different chemical and mineral composition of the base clinker.

The tested dosage range of the ShCA KEPTONITE is within the optimum ratio between technical characteristics and reasonable price.

In conclusion, the use of ShCA KEPTONITE with optimized dosage-rate in fiber-reinforced concrete joint-less flooring system for high-racking logistic centers gives good perspectives for great durability and high-level of performance of these type of special building constructions

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