

CONCRETE IMPERMEABILITY INCREASING ON THE BASE OF NEW INTERNAL CAPILLARY CRYSTALLINE-HYDRATION STRUCTURES

Valeriy Borisov Naydenov, Ivan Alexandrov Rostovsky

Institute of Mechanics, Bulgarian Academy of Sciences, Sofia, Bulgaria

Abstract

The possibilities for impermeability of the cement-containing fine-grained mortars and concrete increasing by involving of some internally introduced special crystallization additives which, in the presence of water permanently take part in a chemical reaction with a non-hydrated cement component, generating an additional network of non-soluble fine crystals network, disposed in pore structure, capillaries and micro-cracks. Thus create new opportunities for further increasing the concrete cross-section impermeability, including against the ions penetration of aggressive solutions.

The basic physical and strength-deformation performance of various compositions, including such with partially cement replacement in the presence of two types of crystallization additives, are studied. Based on a comprehensive analysis, conducted by using of direct physical methods, the kinetics of dynamic change in time of the new formed hydration structures, determining the effective operation of special additives, is analyzed.

The results obtained are opportunities to improve the efficiency of concrete structures operating in contact with pressure and non-pressure water, as, in most cases, eliminating the need for additional performance of conventional, often high-expensive, secondary waterproofing systems.

Key words: concrete impermeability, crystallization additives, waterproofing systems

1. INRODUCTION

The Project “DESIGN-BUILD OF BIOLOGICAL TREATMENT PLANT, SOFIA” was finished a year ago (**Photos 1 and 2**). The project includes several special installations for green waste composting and appropriate biological waste utilization. To stock rain and technological water two underground reinforced concrete tanks with volume more over of 1000 m³ were designed with two coats high-cost hydro-insulation membrane to ensure absolute exploration water impermeability - **Kubal M.** *Construction waterproofing*, McGraw Hill, New York, Second edition, 2008.

That's the basic reason to propose new respective optimized design solution based on thanks hydro-insulation by using of high quality structural concrete with increased water impermeability achieved on the base of capillary crystalline admixtures.



Photos 1 and 2. Biological treatment plant, Sofia, general view

These types of internally added in concrete mixes special crystallization admixtures take part in chemical reactions with a non-hydrated cement component, generating an additional network of non-soluble fine crystals, disposed in pore structure, capillaries and micro-cracks. Thus create new opportunities for further increasing the concrete cross-section impermeability, including against the ions of aggressive solutions - *ACI 212.3R-10, 2010; ACI Education Bulletin E4-12, 2013; Ramachandran V. Concrete admixtures. Properties, science and technology. Second Edition, 1995; Rixon R., N. Mailvaganam, Chemical admixtures for concrete, 1999; Bentz D., Engineering concrete performance, Concrete International, Vol. 29, Issue 11, 2007.*

In parallel 3 additional efficiency effects will be achieved (**3 in 1**):

- Concrete compressive strength class increasing;
- Maximal concrete water impermeability ($V_v=1$);
- Additional concrete cross-section self-compacting due to the new chemical reactions leading to form new hydro-silicate structures filling to absolute level entire concrete free porosity.

In this moment in Bulgarian concrete practice there is absolutely no-experience to use internal insulating admixtures.

Our proposal to involve CE-marked internal admixture **CRISTEX ADMIX** and **CRISTEX ADMIX HD** should be well motivated taking into consideration some preliminary established datum - nominated concrete supplier and approved concrete mix design with fly-ash as a part of cement replacement.

In the presence of moisture, the chemically active compounds of Cristex products react with unhydrated concrete particles starting a catalytic chemical reaction that deeply generates millions of insoluble needle-like crystals which block the pores, capillaries and small cracks. It thus forms a permanent and effective barrier to water penetration without affecting the permeability to water vapors and allowing the substrate to breathe. Once they have penetrated into the concrete matrix the chemical compounds of Cristex remain permanently active. Latent when the concrete is dry, Cristex reactivates in the presence of humidity restarting the process of crystallization and sealing any new potential cracks caused by settlement, shrinkage, static or dynamic stress, blocking water penetration as well as significantly inhibiting the carbonation process and penetration of aggressive contaminants like chloride, sulfate and nitrate ions. Laboratory assessments have revealed that beside waterproofing the Cristex treatment virtually improves concrete performance by increasing the compressive strength and its resistance in aggressive environments.

Cristex Admix and HD are a specially formulated crystalline admixtures used to waterproof concrete, reduce shrinkage cracks, and increase concrete durability. The secondary benefits include some set retardation, water reduction, lower heat of hydration and increased compressive strength. Cristex Admix is a specially formulated crystalline waterproofing admixture with lower air entrainment and higher compressive strength. It reduces water demand for a given slump and it is compatible with other concrete admixtures such as plasticizers, water reducers, accelerators, and air-entrainers. It is possible it results in increased set retardation. If there is a reason to use of set retarding admixtures, water reducing admixtures and fly ash should be adjusted to achieve required setting times. Cristex Admix is added by 2% of the cementitious material weight (fly ash included) to a maximum of 7 kg per cubic meter.

It is very important to take respective consideration on regional variation of cement, aggregates and supplementary materials may result in some variation in plastic and hardened properties. It is advised to test batches when determining the appropriate mix designs.

Taking into account all above mentioned facts and the importance to avoid any leakage from the water tanks (potential soil pollution) it is needed some preliminary test and research to be performed. The tests should be answered what will be happened if one of those admixtures would be involved into the new insulating solution.

2. TESTS PROGRAM PERFORMED

Six different types of binders (combinations including cement, fly-ash as a partially cement replacement and two types of crystallizations) compositions are tested (see Table 1) – a referent 1 (pure cement), No2 (cement with 2% Cristex Admix), No3 (cement, fly-ash and 2% Cristex Admix), No4 (cement and with 2% Cristex Admix HD), No 5 (cement, fly-ash and with 2% Cristex Admix HD) and a referent 2 (cement and fly-ash).

Table 1. Binder Compositions

Binder composition No	Binder, %		Type and Quantity (% from Binder) of Crystallizator	
	Cement	Fly Ash	Cristex Admix	Cristex Admix HD
1 (referent 1)	100	-	-	-
2	100	-	2,00	-
3	80	20	2,00	-
4	100	-	-	2,00
5 !	80	20	-	2,00
6 (referent 2)	80	20	-	-

At first the kinetics of some important strength characteristics are estimated and discussed on different ages (7, 28 and 90 days) (see table 2).

Table 2. Bending (R_b) and compressive (R_c) strength

Binder composition No	Age, days					
	7		28		90	
	R_b , MPa	R_c , MPa	R_b , MPa	R_c , MPa	R_b , MPa	R_c , MPa
1	6,40	32,70	8,43	37,60	9,36	38,40
2	6,10	29,70	8,20	36,50	9,81	40,90
3	5,60	22,40	6,09	28,70	8,30	38,40
4	4,38	24,30	6,75	29,20	7,93	33,30
5 !	3,09	14,90	3,56	17,00	3,96	19,90
6	6,21	26,70	6,80	32,40	8,80	35,40

At 7- and 28-days of age the binder referent 1 (No1) demonstrates the best strength-characteristics performance, obviously. This can be well explained with the absence of cement replacement material (no fly-ash content). It is well known that the fly-ash involvement in cement containing composite is tends to retard the basic strength characteristics increasing.

Table 3. Porosity

Composition No	Total pore volume, cm ³ /g		
	Age, days		
	7	28	90
1	0,117	0,093	0,096
2	0,085	0,083	0,089
3	0,155	0,097	0,106
4	0,105	0,085	0,075
5 !	0,106	0,110	0,129
6	0,118	0,115	0,115

Opposite, in time the strength is tended to be influenced positively due to the fly-ash additional activity. It can be added that the Cristex and HD key role is reflexed after respective ageing. It is clearly identified that the strength characteristics of the composites with cement fly ash and Cristex studied (No2 and 3) dominated at 90-days of age.

At the same time it could be remarked that the composition No6 demonstrate the worst strength indexes, probably due to the some kind of incompatibility between fly-ash content and Cristex HD. That gives enough reason to avoid this combination in future design procedures.

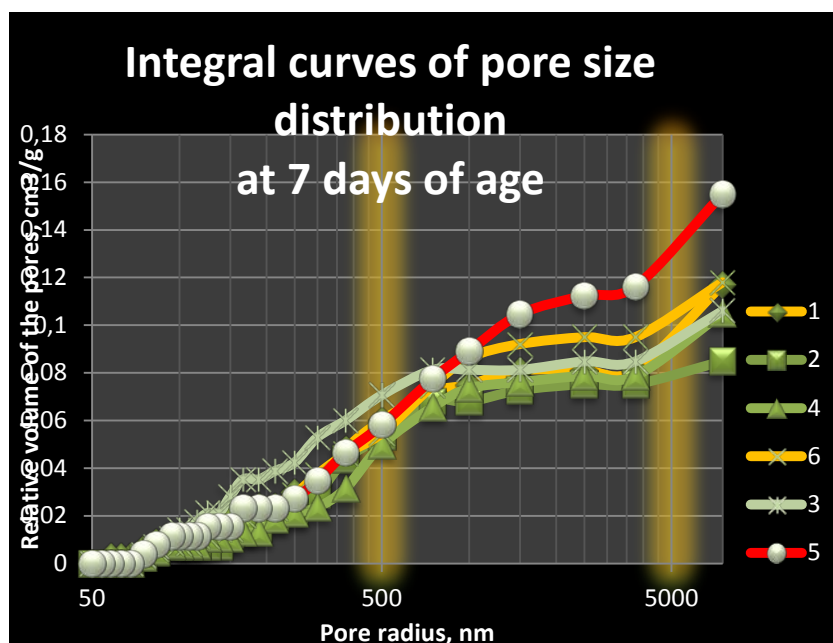


Fig. 1 Pore size distribution at 7 days of age

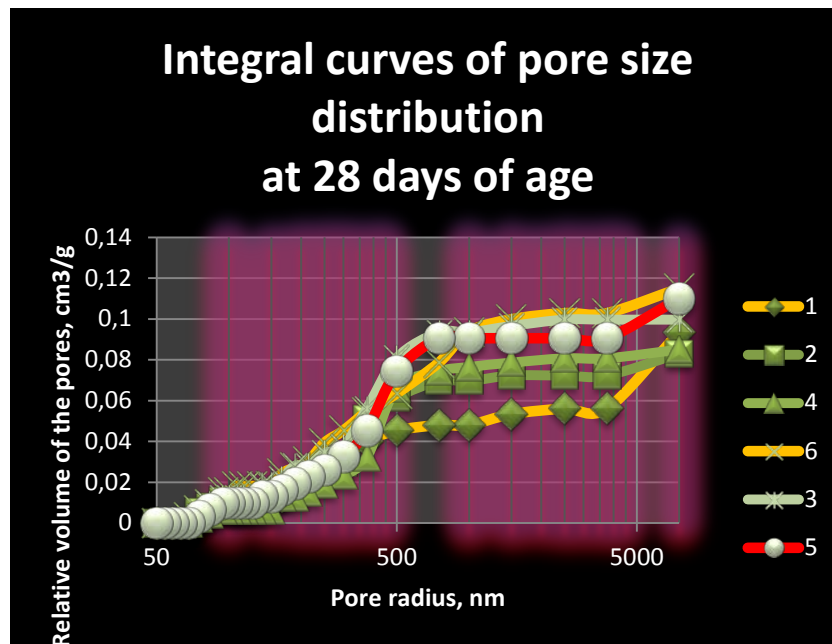


Fig. 2 Pore size distribution at 28 days of age

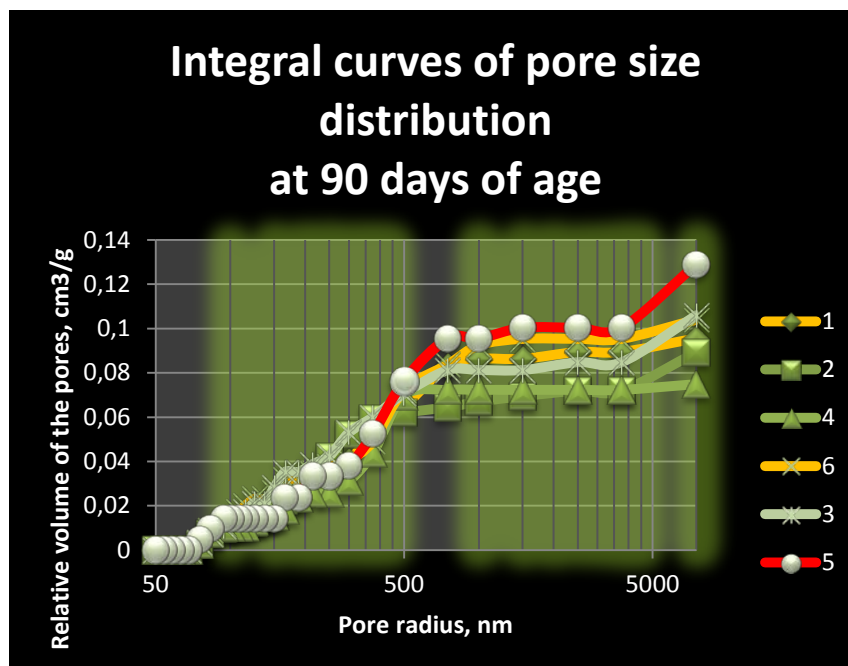


Fig. 3 Pore size distribution at 90 days of age

Trying to explain the above mention consideration respective pore size distributions are tested by using of mercury porosity test device. The results are given in **Table 3**.

The total pore volume of the composition No5 (Cristex HD + Fly-Ash) are highest - more than 50% compared with the respective composition without Fly-Ash (No4). At the same time can be concluded that composition No4 (Cristex HD) demonstrates lowest pore volume at 90 days of age. This is not corresponded to the respective strength indexes (**Table 2**). Something more, composition with Cristex without Fly-Ash (No2) shows better performance compared with Fly-Ash (No3) at all test's ages.

Taking into account the pore size distribution and the fact that concrete water permeability strongly depends on the pores with radius up to 500 nm, the **compositions No2, 3 and 4 are preferable**.

Trying to explain the strength-porosity results obtained some additional structural test are performed (thermal analysis, XRD and SEM), excluding composites on the base of **Cristex HD (No4 and 5)** due to the obviously reasons (see Fig. 4 and 5).

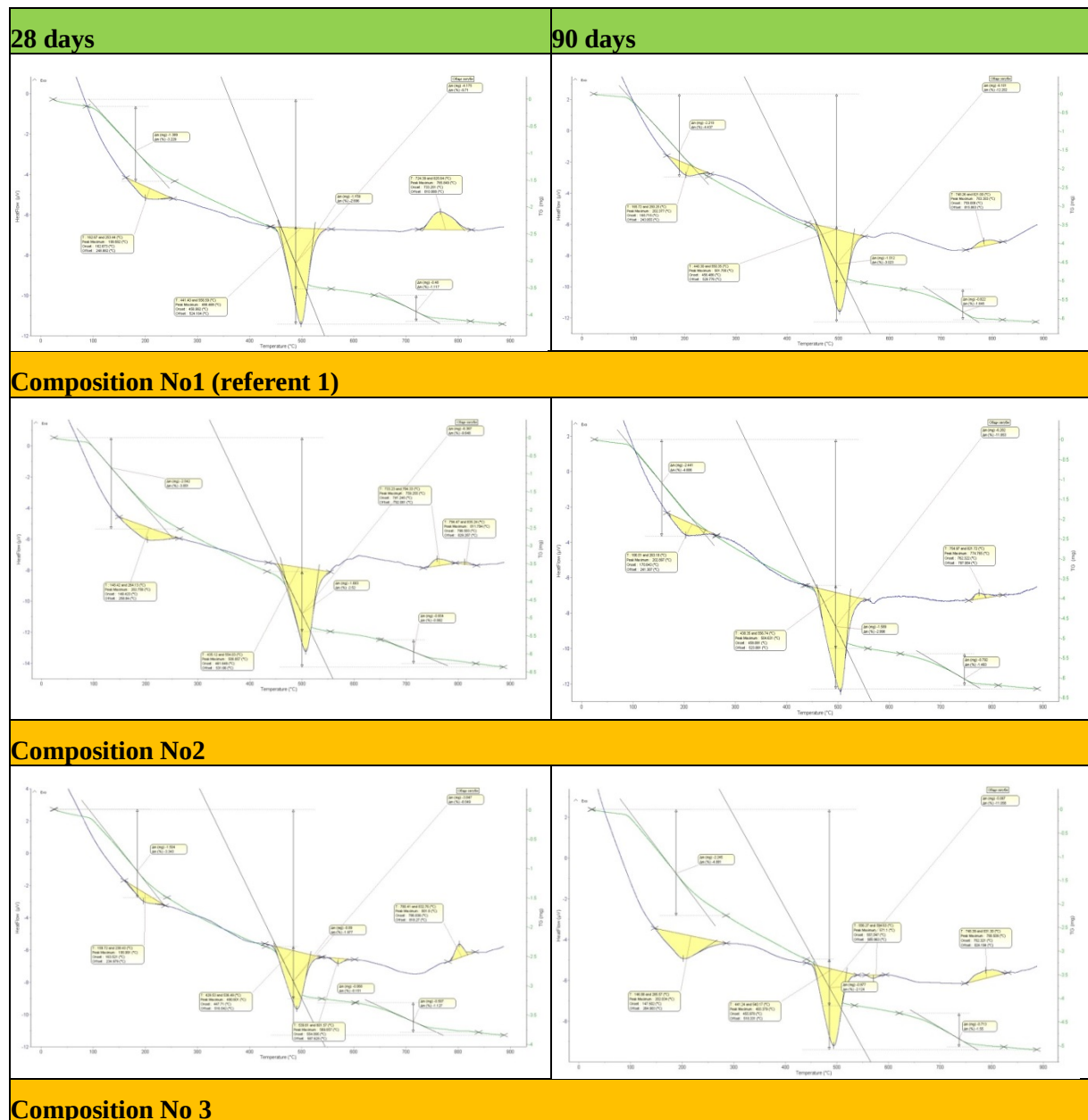


Fig. 4 DTA-comparisons No1, 2 and 3

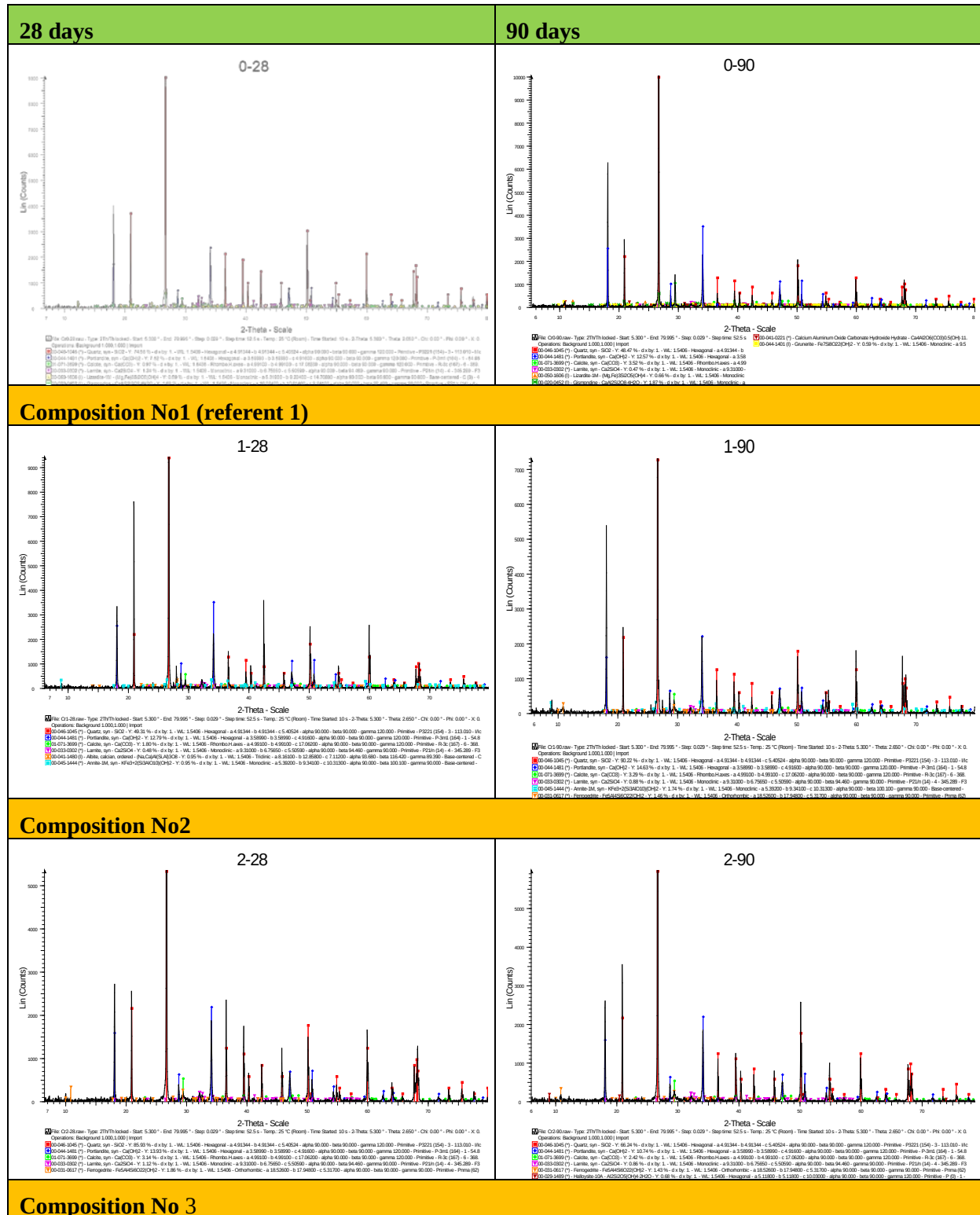


Fig. 5 XRD-comparisons No 1, 2 and 3

The complex analysis and the structural tests give enough reasons to confirm the **best performance** of composites containing **Cristex Admix with and without Fly-Ash (N2 and No3)** in the mix design.

3. CONCLUSION

Cristex Admix is a specially formulated crystalline admixture used to waterproof concrete, reduce shrinkage cracks, and increase concrete durability. The secondary benefits include set retardation, water reduction, lower heat of hydration and increased compressive strength. **Cristex Admix** is a specially formulated crystalline waterproofing admixture with lower air entrainment and higher compressive strength.

All preliminary tests performed show the best result for the binders based on pure cement and cement and 20% fly ash with incorporated Cristex Admix in the mix design.

Trying to introduce some kind of cement replacement material as part of binder content (fly ash) it is established that there is no reason to incorporate in concrete mix design the internal capillary admixture types Cristex Admix HD - the fly-ash presence has to be excluded absolutely.

This approach was successful used for concrete structures building of above mentioned water tanks. The preliminary design solution based on hydro-insulation was replaced by using of high quality structural concrete with increased water impermeability achieved on the base of capillary crystalline admixtures (Cristex Admix).

At the same time it needs to underline that the use of this advance approach not compensate for eventual poor concrete practices. The concrete mix design should be perfect and the fresh concrete must be fully consolidated and properly cured. The special attention should be paid to the proper joint execution in correspondence of good concrete practice, additionally.

REFERENCES

- Kubal M. Construction waterproofing, McGraw Hill, New York, Second edition, 2008.
- ACI 212.3R-10 Report on chemical admixtures for concrete, Reported by ACI Committee 212, 2010.
- ACI Education Bulletin E4-12, Developed by ACI Committee E-701, 2013.
- Ramachandran V. Concrete admixtures. Properties, science and technology. Second Edition, Noyes Publication, New Jersey, 1995.
- Rixon R., N. Mailvaganam, Chemical admixtures for concrete, Third Edition, E&FNSpon, London, 1999.
- Bentz D., Engineering concrete performance, Concrete International, Vol. 29, Issue 11, 2007.