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PRESENT STAGE OF GELIVITY RESISTANT CONCRETE FEATURES

BY

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Abstract. The characteristics of the concrete gelivity by imposing strictly conditions to the composition are studied. We observed the new formed structure so as components from cement stone, vulnerable at freeze thaw, to be lower as percentage. The resulted concrete structures will have the main characteristic of reduced cement consumption, high exigencies of freeze thaw durability and low costs.

Key Words: Concrete; Freeze Thaw; Admixtures; Cement; Mechanical Strength.

1. Introduction

Concrete world consumption is estimated at 5.5 billion m^3. It is the most used material by peoples, beyond water. The main component material of concrete is cement. Hydraulic concrete is yet known from time of the Romans. "Modern" concrete came the half-nineteenth century, when in England, John Aspdin obtained Portland cement by burning a mixture of fine clay and limestone (1824).

Each construction or element of construction must meet a set of technical requirements or principal technical and economical demands, concerning durability in time, fire resistance, building strength and stability, physical and hygienic conditions, architectural, economic and organizational.

Durability means normal duration of operation in time for main elements of construction, without loss of quality necessary for optimal exploitation and it can be: high (I^{st} degree) and is over 100 years; middle (II^{nd} degree) between 50 and 100 years; normal or usual (III^{rd} degree) between 20 and 50 years. Buildings with a life service under 20 years are called *temporary*.

Durability is determined by the materials that were used, design and execution manner, operating conditions and maintenance referring to strengths of materials and construction elements at different actions such as: freeze–thaw, moisture, corrosion, biological action of micro-organisms and the environment: atmospheric agents, smoke, gas and other pollutants from the inside.

Experience gained in time, concerning the performance of concrete structures in aggressive environments, with recent knowledge of some physical-mechanical and chemical properties of concrete and reinforcement, led to the conclusion that, depending on operating conditions, certain elements suffer degradations, after longer or shorter periods of service.

Concrete gelivity is a feature which considers its behavior to freezing–thaw cycles. Behavior at freezing–thaw is a characteristic of concrete durability determined by its porous structure. The importance of this feature drifts from rapid degradation of concrete elements saturated with water, under conditions of repeated freeze–thaw cycles with consequences on constructions resistance and stability.

By repeated freeze–thaw cycles concrete is subjected to damage, due to alternative efforts, caused by water volume increase which freeze in the pores thereof. If the concrete is dry, then freeze–thaw does not destroy him. Gelivity degree of concrete is characterized by the number of cycles of successive freeze–thaw, in test conditions, that samples can resist without a loss of weight greater than 5% and reducing their resistance with more than 25%. Gelivity degree is important for works that operates in harsh climatic conditions and especially to concretes with variable water levels.

Losing of weight is not a sufficient sensitive measure of damage caused by frost and thaw, because often, especially in case of concretes with lightweight aggregates, it is found even an increase in weight due to water intrusion into the internal cracks, formed due to freezing–thaw. Therefore, most important for assessing gelivity is the exterior aspect of samples, taking into account that damage begins by rounding the edges and corners.

Neither loss of compressive strength doesn't constitute, in all cases, sufficient sensible criteria in order to evaluate gelivity effect, because internal cracks affect less resistance to compression.

2. Parameters which Influence Concrete Gelivity and its Formulation

Influences and effects of repeated freezing–thawing are taking place with a different intensity related to

a) the exposure conditions and the environment;
b) structural characteristics of the material.

Temperature and water are the main factors at which environment acts destructive against concrete. The exposed material reaches gradually environment temperature, between exterior and interior layers of concrete developing a temperature gradient. From here we can conclude that freezing takes place gradually and not instantaneously. Temperature for freezing water into concrete varies with reference to pores and micro cracks dimensions. Experimental studies have shown that most important changes in the structure of concrete are produced in temperature range of $-10°C \ldots -45°C$. Time of exposure to negative temperatures and the rate of their decrease will influence the formation of ice, so the default damage of concrete.

Humidity will influence ice formation process in porous bodies, experimental tests on concrete pointing humidity values which can influence behavior to repeatedly freezing–thaw.

Concrete components through porosity and pore structure will have variable influences on freezing–thaw behavior of concrete. In the matrix there are pore gel, capillary pores, bubbles of entrapped air and entrained air. Water contained in large cracks and pores (10…4 cm), freezes under identical conditions as free water. Saturates large pores have a negative influence on durability of concrete in freeze–thaw conditions. If the degree of saturation with water will be reduced, also the influence of pores on the overall freezing–thaw behavior will be reduced.

a) Capillary pores influences derogatory freezing–thaw behavior, through

a) capillary pores volume;
b) capillary pores character (not linked or interlinked).

At their turn, capillary pores volume and their character is given by W/C ratio, researches carried out relieving, correlation between this ratio and gelivity resistance of concrete, but also it's favorable influence for reduced W/C ratios.

b) Interlinked pore system increases sensitivity of concrete to destructive action of repeatedly freezing–thaw and for this reason is necessary the achievement of a concrete with low W/C ratio, to be exposed at freezing–thaw cycles to an age when, as a cause of advanced hydration degree, capillary pores are not interlinked.

c) Entrapped air (and entrained air) has a role of "expansion basin" at the moment of frost, when water infiltrates in this goals because of hydraulic pressure created by volume expansion with 9% of the water from saturated pores. In conclusion, growth of ice particles from cement stone microstructure is locked or limited. At thaw, water returns from the goals toward capillary network, and protection assured by this goals system is valid for new cycles of freezing–thaw process.

d) In gel pores freeze can took place at high negative temperatures (-85°C), which in normal conditions can't be possible (in our country).

e) Freeze–thaw mechanism is a very complex phenomenon and exists several theories, including the one below. By lowering the temperature around 0°C, free water freezes in pores with a 10^{-4} cm radius. Freeze starts from the concrete element surface and continues into the deep as it reaches the freezing point of water. Freezing water occurs at temperatures as low as pores are finest and adsorption forces are more intense on the water volume contained in pores.

Water concrete is actually a solution (of different substances from environment or even from cement mineralogical components) where solvent, by freezing let place for solutions with high concentration and also with it, the freezing temperature will drop.

When water freezes, in concrete pores took place following phenomena:

a) by increasing the volume, ice crystals are putting pressure against not frozen water (powers hydraulic pressure theory), forcing it to pass through pores walls;

b) as a cause of differences in concentrations of aqueous solutions from gels and capillary pores (microscopic segregation theory), will manifest osmotic pressure and under its action, water from gel pores will pass through capillary walls, in capillary pores.

The two contrary pressures causes a swelling pressure of saturated concrete and therefore appearance of a tension state which, if exceed concrete tension resistance value, will lead to appearance of micro-cracks in its structure.

If the freezing–thaw occurs in the presence of water or only in conditions of high humidity, water infiltrates through micro cracks formed from previous freeze process, so that degradation of concrete gains in time, through repeated cycles of freezing–thaw, a cumulative character.

As a direct consequence of damage of the concrete structure, its resistances will decrease, increases the permeability to water and thus is quick disintegration of concrete.

There are several ways of assessing resistance of concrete to gelivity:

a) *Indirect methods*, who appreciate this feature, according to porosity and pore structure, water absorption, volume of entrapped air.

b) *Direct methods*, which consider this characteristic through variation of compressive strength, bending tensile stress, dynamic modulus of elasticity, dimensional change or loss of mass.

c) *Gelivity degree*, defined as the number of freezing–thaw cycles until testing samples exposed in saturated state does not record a reduction of compressive strength more than 25%, compared to witness samples.

A standard cycle of freezing–thaw involves maintaining test samples four hours to a temperature of $-17^\circ \pm 2^\circ$C, followed by another four hours in water at a temperature of $+20^\circ \pm 5^\circ$C.

Depending on gelivity degree, are three different classes of gelivity: $G50$, $G100$, $G150$, where G means degree of gelivity and 50, 100, 150 number of cycles for which mentioned limits weren't exceeded.

3. Observation that Concrete Mixes Given by Technical Data Lead to Unjustified Mechanical Resistances

To achieve gelivity performances, usually are used supplementary cement dosage or imposed some strictly composition conditions, such as: W/C ratio, type of cement, fine aggregate percent. From working conditions of designed concrete it results a hardened concrete with mechanical resistances over required ones, unjustified from technical and economical point of view.

Influence of cement dosage on the fresh and hardened concrete properties, varies by considered feature. W/C ratio is small as much as the dosage of cement is higher (Fig. 1).

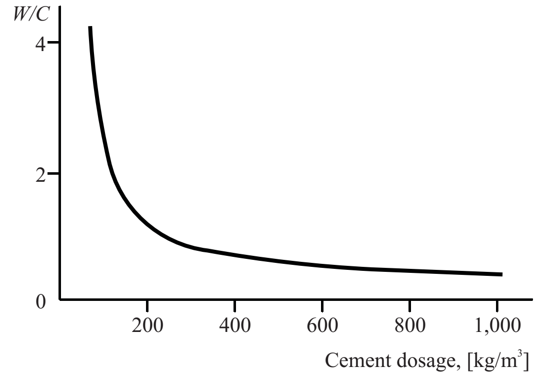

Fig. 1. – *W/C* ratio variation *vs.* dosage, at normal consistency.

Apparent density of fresh concrete (*1*), but also of the concrete after 28 days of hardening (*2*), increase with dosage until a level of 300 kg of cement for 1 m^3 of concrete, remains stationary until a dosage of 400 and for greater dosage begin to decrease, as we can see in Fig. 2.

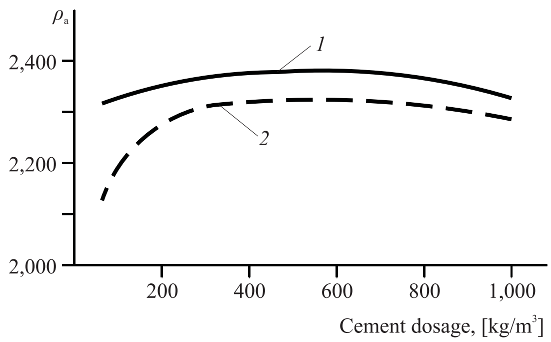

Fig. 2. – Variation of apparent density of the concrete *vs.* cement dosage.

This influence has the following explanation: at low dosages, the gaps between aggregates granules are not completely filled with cement paste and then apparent density of concrete is low; for a dosage of 300. . . 400 kg of cement, gaps are filled and we get to the highest apparent density. If we continue to increase dosage, the volume of cement paste exceeds gaps volume between aggregates granules, so they no longer support themselves, between them being interposed cement paste.

If we take into account compression strength of concrete, it increases proportionally with dosage up to 300. . . 350 kg cement to 1 m^3 of concrete. When this dose is exceeded, increased resistance is not proportional to the dosage, but less and less, as seen in Fig. 3.

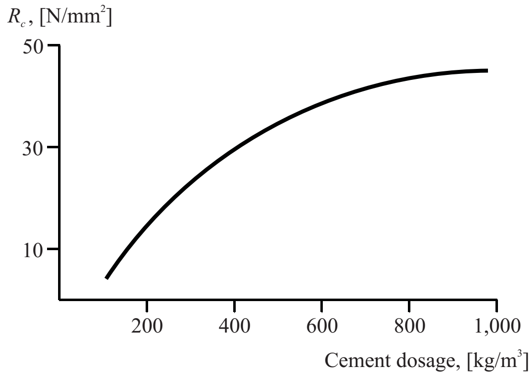

Fig. 3. – Variation of compressive strength of concrete according to cement dosage.

From here we can conclude that, to obtain high resistances to compression, excessive growth of cement dosage, excepting the fact that produces a rise of expansion shrinkage, it is not indicated nor from economical point of view.

Resistance to bending tensile stress also increases proportionally with dosage up to 350. . . 400 kg of cement to 1 m^3 of concrete. Above this dosage resistance remains constant, and for greater dosages, decreases. This decrease is due to the fact that at high dosages, concrete contraction increases, and thus producing crack in the mass of hardened concrete, and under strain effort, cracks are opening more and thereby reducing the useful concrete cross-section.

From the above-mentioned it is clear that exaggerated dosage of cement is not justified nor technically, nor economically.

4. Means to Improve Concrete Freeze Thaw Behavior with Admixtures which Alter Structure of Cement Stone

Mineralogical composition of cement has a relatively small influence against gelivity. Among the mineral components of cement clinker, the most sensitive to freezing–thaw is tricalcium hydroaluminate. Trass cements has a larger amount of mixing water, making concretes more gelive. Cement dosage influences sensibly, freezing–thaw behavior of concrete. When the content exceeds 250. . . 270 kg gelivity resistance index remains at a constant value.

The gelivity index represents the ratio between freezing–thaw numbers of cycles till destruction of concrete and amount of cement expressed in kg/m^3.

The amount of water contained in concrete strongly influences gelivity resistance; also an important role it plays environment humidity of keeping testing samples.

Thus, the moisture saturated concrete has a much lower resistance than concrete kept only in atmospheric humidity (Fig. 4).

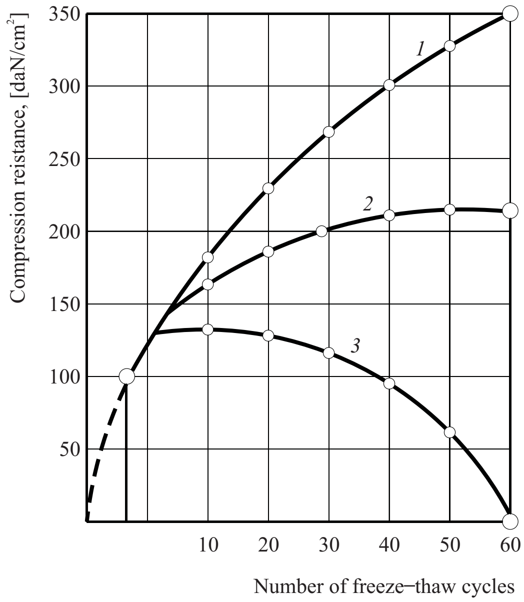

Fig. 4. – Humidity influence on gelivity.

Increasing resistance to gelivity can be achieved by growing concrete compactness and impermeability. We could say that all means which lead to compactness growth can be used for this purpose (increasing resistance to freezing–thaw). Of all these means, a particular role is played by plasticizers, both air entrainment and peptized ones. Air entrainment admixtures reduce the number of open pores and thereby increase the impermeability of concrete, limiting the possibility of water migration. At the same time, air contained in mineralized bubbles plays the role of buffer spring, damping ice crystal pressure on concrete.

Technical parameter for concrete composition analysis, with influences on all characteristics of cement composite materials, is the *water/cement ratio* (W/C).

Studies have led to the conclusion that increasing W/C ratio will produce

a) increasing total porosity of concrete;
b) decrease the proportion of gel pores in favour of capillary pores.

These two sequels of W/C ratio growth will have adverse consequences on physical and mechanical characteristics of concrete: increased permeability, reduced mechanical resistances, weak resistance to freezing and thawing and corrosion.

1. Admixtures are substances that, introduced in determined quantities in suspensions, mortars or concretes, change their properties by virtue of some physical and chemical actions.

The main categories of admixtures that produce changes of concrete characteristics are

1. Admixtures modifying the processes of binding and hardening.
2. Waterproof admixtures.
3. Surfactant admixtures.

Below, we refer with precedence to waterproof, surfactant and air entrainment admixtures, which by their action provide a good behavior in the range of concrete resistance to freezing–thaw.

2. Waterproof admixtures are substances that increase capacity of concrete to resist at water penetration, through

a) reducing concrete permeability to pressurized water action;
b) reduction of capillary porosity and, implicitly, of water capillary ascension in concrete;

Several substances are used for their waterproofing action namely

a) inert mineral powders have the role to fill aggregate granularity in fine part (any increase of water dosage should be correlated with increasing dosage of cement);
b) silicate mineral powders binds chemically $Ca(OH)_2$ in shape of hydrosilicates with reduced alkalinity and good binding properties. Also, they improve behavior at sulphate aggressive action (pouzzolana, dolomite) implicitly increasing impermeability degree;
c) mineral powders with colloid properties (bentonitic clay, fine grind limestone) in contact with water are swelling increasing impermeability and resistance to aggressive chemical action;
d) products with colloidal properties, resulting from reaction of some substances with the cement hydration products;
e) surfactant admixtures, favourable effect they have on concrete waterproofing, is given by reducing W/C ratio, modification of pores dimension and their distribution (plasticizers admixtures), stopping capillary system (air entrainment admixtures) and reducing capillary height (hydrophobic admixture).

3. Surfactant admixtures that are adsorbed on the surface of cement granules thus changing the surface tension of solid liquid–air system. In their case we refer to air entrainment and mixed admixtures.

4. Air draw admixtures are surfactant substances which added in small proportions in concretes, draw and stabilize a big number of fine air bubbles, uniformly distributed in the mass of material which can cause a restructuring of composition where introduced.

If such substance is added to cement during grinding, it will form monomolecular films on the surface of cement granules, molecules orientating with hydrophilic ending toward cement grain and with hydrophobic ending outwards, so that the grain becomes hydrophobic. If we note molecule with a line finished with a circle, representing hydrophilic ending, hydrophobic cement grain appears like the one presented in Fig. 5. Cement hydrophobicity is achieved by an admixture quantity less than 1% from cement weight. Hydrophilic cement has a much lower sensitivity to atmospheric humidity and it is not cloggy at storage. Hydrophobic film, mixing in the mortar mixer, is removed and the admixture is dissolved in water, so the hydration of cement flows normally or only with a slight delay.

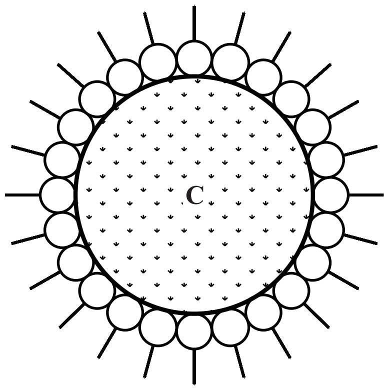

Fig. 5. – Granule of cement with admixture hydrophobic film.

When dissolving admixture in water, or if it was dissolved at the beginning in mixing water and cement was without admixture, then reducing the surface tension of water is formed in the mass of cement paste in concrete, a dispersion of air microscopic bubbles connected through capillary channels. In fresh concrete mix these air bubbles increase its mobility and permits achieving same consistency with a lower W/C ratio. In hardened concrete, the dispersion of air causes a slight reduction of apparent specific weight and compressive strength in relation to the volume of dispersed air. If the volume of air does not exceed 3...4% of the concrete, then its durability is much improved, through the fact it becomes more impermeable and therefore more resistant to both repeatedly freezing–thaw action and corrosive solutions action.

5. Antifreeze additives have the role to decrease temperature of freezing water in the concrete, being used when working on coldness, as a protection measure against concrete freezing. These additives has to show at the same time hardening acceleration action, reducing time to achieve sufficient strength to take over efforts developed by internal freezing.

In our country is used ”Antigero” additive with a down freezing point of water at $-10°$C, having both hardening accelerator and air draw actions.

The use of additives in cement concrete composition has to be made carefully, because the products used as additives have complex actions. Not respecting prescribed dosages, experimentally determined, lead to achieving of undesired results or even to concrete compromise.

5. Conclusions

Admixtures can be used advantageously in modern concretes. They are used for ”curative” or ”preventive” purposes, for example, air-draw; they are used as ”aids,” for example acceleration of hardening; and they are used for purely money-saving purposes, for example water-reducers. The full list of benefits is impressive for both producer and consumer of concrete. As has also been noted, however, these benefits are contingent on proper use and knowledge of side effects and other hazards. An admixture cannot compensate in case of inferior materials or bad practice. In most cases there are alternatives worth consideration on economic as well as quality counts.

Admixtures in every-day concreting operations will continue to have an important place in concrete technology. Their successful use depends upon proper diagnosis and correct prescription for each situation. This, in turn, requires not only a basic knowledge of concrete technology, but also recognition that an admixture requires modification of procedures. It also implies recognition of the essentially chemical nature of admixtures and the processes they are involved in. The architect or builder need not become an expert as concerns the admixtures, but it has become evident that it is to his advantage to be familiar with their type, nature, and general effect.

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STADIUL ACTUAL PRIVIND CARACTERISTICILE BETONULUI REZISTENT LA GELIVITATE

(Rezumat)

Experienţa acumulată în timp, cu privire la performanţele structurilor din beton situate în medii agresive, împreună cu recentele cunoştinţe privind unele proprietăţi fizico-mecanice şi chimice ale betonului şi armăturii, au condus la concluzia că, în funcţie de condiţiile de exploatare, anumite elemente suferă degradări, după perioade mai lungi sau mai scurte de funcţionare.