Prevention Strategies for Pathologic Shrinkage Cracking

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ABSTRACT. *One of the causes of pathology cracking is shrinkage phenomenon. There are different types of shrinkage, but drying one and autogenous one are the most important in normal concrete and high strength concrete. After the global analysis of three databases on shrinkage test, we think that the study of shrinkage should be done around concrete structure. In this way, and recognising the great importance of the interfacial transition zone, we propose three strategies for trying to reduce pathology cracking, which can be especially dangerous in marine environment.*

KEY WORDS: *Shrinkage, Concrete Technology, Durability*

1. Introduction

There are many causes that can produce pathologies in reinforced concrete: physic factors (plastic shrinkage, thermal shrinkage, direct loads, induced deformations, drying shrinkage) chemical processes (chemical shrinkage, autogenous shrinkage, alcali reaction aggregates, steel corrosion, carbonatation phenomenon) and also, biological attacks (vegetation settled over concrete structures, micro-organisms who can attack concrete paste through humic acids).(CEB, 1996) (Calavera, 2005) (Perepérez y Barberá, 2005)

One cause of pathology that can appear in marine environement is the excessive shrinkage cracking. We must admit that shrinkage cracking is not the only cause of excessive cracking in any reinforced concrete piece, but it is true that is one of concrete cracking causes which appears without any kind of external load. (CEB, 1996) (Perepérez y Barberá, 2005)

Excessive cracking makes easier the transport of chlorides inside the mass of concrete, increasing concrete pathology process on one hand, and accelerating the steel bars corrosion on the other hand.(CEB, 1996)

2. Shrinkage cracking

Nowadays we can distinct between seven types of shrinkage. In fresh concrete, we have chemical shrinkage, produced because the volume of the primary elements is larger than the products of the reaction, and plastic shrinkage, that appears after a loose of the superficial moisture.

In hardened state, we can distinct, firstly, autogenous shrinkage. Cement matrix materials suffer a volume reduction when hydration is on, after beginning setting. In this volume changing, there are not included all those factors that include or loose any substances, temperature changes or the application of a load or its restriction (Perepérez y Barberá, 2005).

Drying shrinkage is a volume reduction due to the loose of the humidity that has the water film rounding cement gel particles (Delibes, 1993). Carbonation shrinkage appears when porlandite is dissolved into carbonate structures caused by the action of CO2 (Fernández Cánovas, 2007). Thermal shrinkage is present in large concrete volumes when hydration heat is dissipated slowly, producing a contraction in the big mass (Mehta et alters, 2004). And last, we have the swelling phenomenon that consists in an increase of volume because of continuous water addiction (Neville and Brooks, 2007).

Lots of factors, such us cement content, water cement relation, quantity of paste, quantity of water and also the strength, had been historically considered as the factors that more influence had in the shrinkage phenomenon, and as a consequence of it, in the pathological cracking that shrinkage phenomenon can produce.

Nevertheless, this situation is changing: as a consequence of the study of three data bases of shrinkage tests (the Bazant one, the RILEM one and the JSCE one) with 506 tests between 1958 and 1998, let us analyse the evolution of concretes and its shrinkage, so the results of shrinkage tests have no relation with strength parameters, neither batching ones.(Bazant, 2008)(RILEM, 1999)(JSCE, 2003)

The database object of this paper is conformed by the union of three databases: Bazant, Rilem and JSCE database on shrinkage. The method of unifying these three compliance of dates is taking Bazant’s one as reference and complementing it with Rilem’s and JSCE’s databases.

Furthermore, the database is increased with recent dates obtained in different resources, such us Gómez- Soberón investigation (Gómez,- Soberón), Sanguinetti report (VVAA, 2005), the Wisconsin Highway Research Program (VVAA, 2006), Virginia Transport Research (Mokarem , 2002) and Chinese Researches (VVAA, 2004) .

3. Concrete structure: a different point of view

These problems are exposed from the point of view of the concrete structure. The same that is not possible to study human nervous system without analysing the neurone, we think that the shrinkage phenomenon cannot be seriously studied without the study of the concrete structure. So we start from the components of concrete: cement paste, aggregates, water, non hydrated cement, pores and the transition zone.

It is also really important the study of the hydration reaction, and the physiological differences between a normal concrete and a high strength concrete. A normal concrete, after the reaction, has a net of huge pores that are well communicated in between. Nevertheless, a high strength concrete owns a net of fine pores that have a less grade of interrelation.(Aïtcin, 1998)(Malhotra and Mehta, 2008)

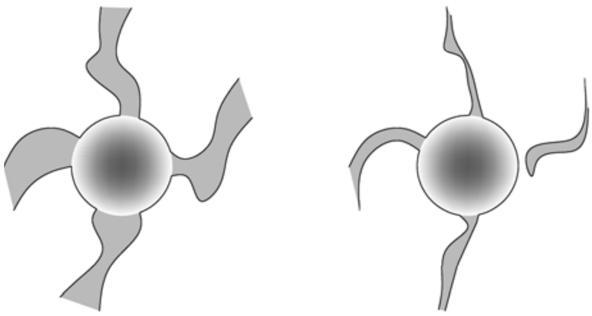

Figure 1. *Pore structure in an ordinary concrete and in a high strengh concrete*

These structural differences have as a result that the shrinkage deformation in both types of concrete is really similar. The normal concrete, with a hide pore net, makes easy the drying shrinkage, that is proportionally bigger than the autogenous. But high strength concrete, with a thinner pore net, have a less proportion of drying shrinkage and a bigger of autogenous. As a result, both systems have a really similar total shrinkage, so we can conclude that both types of shrinkage are compensated showing really similar deformations in both concretes.

This affirmation is confirmed after a statistic study of the data bases during the time, it means, showing the evolution of concrete resistance along three periods of time: from 1958 to 1969, from 1970 to 1989 and finally, from 1990 to 1998. We can conclude that the content of cement have been increased and logically, its resistance, but the total shrinkage deformation have not been increased, as these tables show:

RESUME OF MIXING AND MECHANICAL CHARACTERISTICS					
Test	**relation w/c**	**content c**	**V aggregate**	**V cement paste**	**fck (28)**
Shrinkage 58-69	0,50	323	683,46	316,54	41,30
Shrinkage 70-89	0,48	375	680,46	319,54	46,45
Shrinkage 90-98	0,34	450	689,85	310,15	73,70

Figure 2. *Resume of mixing and mechanical characteristics*

RESUME OF MECHANICAL, AMBIENT, DURATION OF THE TEST AND DEFORMATION					
Test	**E (28)**	**temperature (ºC)**	**humidity**	**duration (days)**	**shrinkage deformation**
Shrinkage 58-69	25.860	20	50	540	**539**
Shrinkage 70-89	32.790	20	60	772	**494**
Shrinkage 90-98	43.400	20	60	360	**465**

Figure 3. *Resume of mechanical, ambient, duration of the tests and deformations*

4. Interfacial Transition Zone

The interfacial transition zone is placed in the in the most near surface of the aggregate, where the microstructure of the cement paste hardened differs the one that is own of the mass placed to an a bit major distance. (Soroka, 1977)(Perepérez, Barberá, 2005)

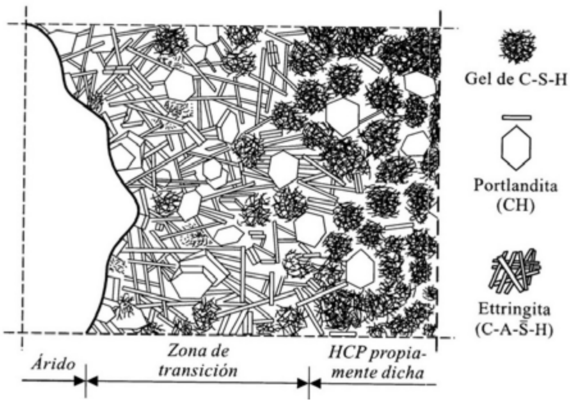

Figure 4. *Interfacial transition Zone (Mehta, 2004)*

The mechanisms of water transport within the concrete, more specifically the diffusion, capillary suction and penetration caused under pressure, are favoured before a cracked structure (CEB, 1996).

The interfacial transition zone in ordinary concretes is the weakest phase in concrete structure and it is the place where the tensions are concentred (specially in light aggragates). Because of this, appears a young micro- cracking in the interfacial transition zone, before the application of any load. This properties and the young micro- cracking of the interfacial transition zone give us an explanation of the permeability of the concrete is bigger than the permeability of the cement paste, because the interfacial transition zone is the weakest phase of concrete, as named before (Perepérez, Barberá, 2005) (González Isabel, 1993)

All these factors must be taken into account in the study of the physiology of concrete. The vital importance of the interfacial transition zone, and its configuration, that depends on the type of aggregate, the type of cement, water/ cement relation,...(Neville and Brooks, 2007) (Delibes, 1993)(Mehta et alters, 2004)(Perepérez y Barberá, 2005)(Fernández Cánovas, 2007)

5. Prevention strategies

Once analyzed the problem, it raises possible solutions, always from the point of view of the structure of concrete, to prevent the shrinkage as a cause of pathological cracking in concrete placed in marine environments.

5.1 *Use of hydraulic additions*

The use of hydraulically active additions give rise to a second hydration, that as beneficial consequences to avoid the pathological cracking we can highlight: bleeding and segregation tendency reduction, decrease in the mixing water for constant consistencies and decrease of the heat of hydration. (Neville, 2007)

5.2 *Type of aggregates*

Maximum size of aggregate has an influence in shrinkage. The reason is that in a determinate volume of concrete, a high volume of aggregates become in a less volume of cement paste, so less deformation caused by shrinkage phenomenon will appear. (Fernández Canovas, 2007)

The most important factor that affects shrinkage deformation is the total content of aggregate, due to it has the function of limit these deformations. We must remember that a certain volume of concrete is formed by a volume of cement paste plus a volume of aggregate, so the higher volume of cement paste give us a less volume of aggregates. (Agranati, 2008) It means that the maximum size of aggregate is not a decisive factor, but a higher maximums size of aggregate, there will be a higher volume of total aggregate, and this is a relevant factor in shrinkage phenomenon. (Neville and Brooks, 2007)(Mehta et alters, 2004).

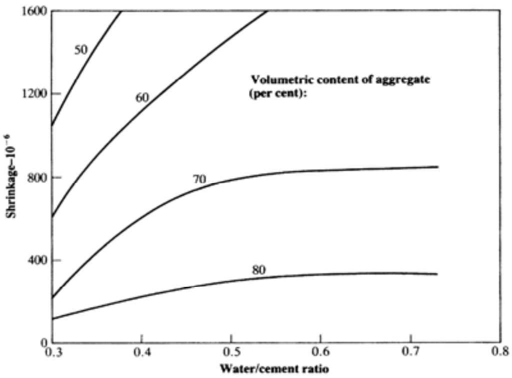

Figure 5. *Influence of the volume of aggregates in shrinkage deformation (Neville, 2007)*

On the other hand, although to a lesser extent, the use of crushed aggregates makes difficult the progress of the micro-cracking of the transition zone. If you also have a high module of deformation, shrinkage will be decreased significantly.

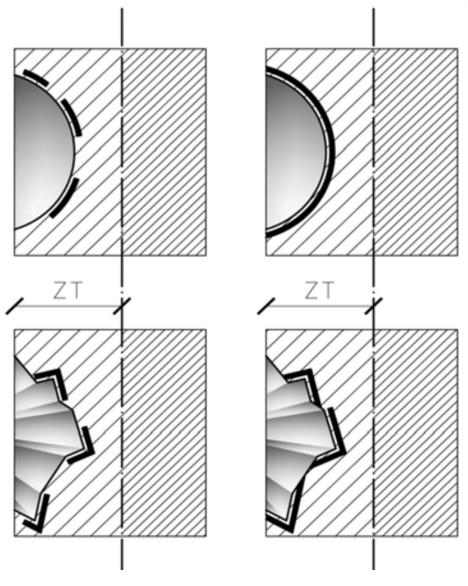

Figure 6. *Evolution of micro-cracking in different types of aggregates*

5.3. *Importance of curing*

Finally, and as a conclusion, it cannot be overlooked the importance of curing. A well done curing brings the amount of water needed for the correct hydrate cement, thus reducing the capillary network, as part of mixing water is lost by evaporation due to it migrates to the surface from any point, remains essential to get an appropriate concrete in marine environments. (CEB, 1996)

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