NON DESTRUCTUVE AIR PERMEABILITY TESTS TO ASSESS THE PERFORMANCE OF THE CONCRETE COVER

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Introduction

Concrete structures in Europe are usually designed, calculated and built for 50 years of operating life expectancy. The normative specifications for utilization of structures in the Middle East region are also 50 years. The durability of a concrete structure or a concrete element is affected considerably by the properties of the concrete cover. Therefore the density and the permeability properties of only few centimetres of the concrete cover represent the main factor influencing the durability of a reinforced concrete structure. International professional associations, as for example the Comité Euro-International du Béton - Fédération International de la Précontrainte (CEB-FIP, Lausanne, CH) have pointed out the importance of this property for the durability.

The properties of the concrete cover are not necessarily identical to those of the bulk, since they are more sensitive to the curing applied. This is particularly the case in hot-dry weather, where the surface may dry quickly, while the core remains relatively wet. An additional issue of interest, with respect to concrete cover, is associated with measures of quality control. The conventional method is based on strength evaluation, which may not be sufficiently sensitive to detect changes which are relevant to durability performance. Such changes are of greater significance with respect to the performance of the concrete cover.

The present study was set to assess the performance of the concrete cover and to determine the efficiency by which it can be characterized using conventional tests as well as non-destructive evaluation by means of air permeability tests (Torrent test, [1/2]).

Experimental

The concretes evaluated in this program were of two kinds, representing low and medium quality, being made of mixes with 200 and 320 kg/m^3, respectively. The mixes were labeled Het 2 (200 kg/m^3) and Het 5 (320 kg/m^3). They had similar workabilities, and similar water content of about 175 kg/m^3. The cement corresponds to CEM I 32.5. The coarse aggregates (19mm maximum size) were crushed Dolomite and the sand was siliceous one.

To simulate the effects of curing on site, spanning from excellent to poor curing, five treatments were applied one day after demolding of the specimens (100mm cubes and 70x70x280 mm bars):

- curing method A, no curing, storage in 30°C/40% RH to the testing age
- curing method B, 5 minutes in water tank, 3 times per day, for 3 days, and after that storage in 30°C/40% RH to the testing age (simulation of intermittent curing on site)

- curing method C, 5 minutes in water tank, 3 times per day, for 6 days, and after that storage in 30°C/40% RH to the testing age (simulation of intermittent curing on site)
- curing method D, 6 days in water tank, and after that storage in 30°C/40% RH to the testing age
- curing method E, 28 days in water tank, and after that storage in 30°C/40% RH to the testing age

The strength of the concretes were determined periodically, up to 90 days. At this age, three tests were applied to assess the quality of the concrete cover with respect to durability and permeability:

- Accelerated carbonation at conditions of 5% CO_2 concentration and an environment of 30^{o}C/50% RH. The depth of carbonation was determined periodically, using the RILEM procedure [3].
- Rapid chloride penetration test using the ASTM procedure [4]. The test results are expressed in Coulomb units, which represent the amount of charge passed during the 6 hours test.
- Air permeability of the concrete, using the Torrent test method [1/2], which measures the surface air permeability. The specimens at 90 days were sufficiently dry (laboratory conditions) so that the moisture content had no effect on the test results.

Results

The results of strength, chloride permeability and accelerated carbonation are presented in Figure 1 to 4. In the present paper the carbonation performance was characterized by the depth of carbonation at 7 days of accelerated exposure (Table 1).

Table 1: Accelerated carbonation test results

			Carbonation depth due to accelerated carbonation: (T = 30°C, 50% RH, CO_2 = 5%) after							
Mix	Curing	Carbonation depth in mm after 90 days in hot/dry conditions, 30°C/40 %RH	2 d	4 d	7 d	14 d	21 d	28 d	35 d	49 d
Het 2	A	8,1	21,4	31,5	35,0					
	B	7,8	18,5	23,3	32,8	35,0				
	C	6,6	15,8	20,6	27,7	35,0				
	D	6,2	13,9	18,0	22,5	32,5	35,0			
	E	4,1	10,6	13,1	17,4	22,4	29,1	35,0		
Het 5	A	4,8	14,6		17,3	21,4	26,5	35,0		
	B	4,2	11,0		13,7	18,0	19,5	23,3	24,5	35,0
	C	3,3	9,2		12,5	16,2	17,9	20,0	22,9	25,0
	D	2,3	6,3		11,0	12,4	15,0	17,1	18,1	22,1
	E	1,4	3,9		7,7	10,0	12,5	13,0	14,0	15,8

The data in figures 1 to 4, shows as expected, the reduction in the effectiveness of the curing (from E to A) is associated with reduction in performance of all the four parameters.

Discussion

The relative influence of curing on each of the four properties is presented in Figures 5 to 8. The reference taken is the 28 days of curing, which represents the laboratory conditions recommended in the EN 206.

It can be seen that within each property, the relative effect of curing is the same for both mixes, the low and medium quality. However, considerable differences can be observed with respect to the relative effect of curing on each of the properties. In the case of strength, the relative influence of deficient curing is relatively small, being 20% or less for curing methods B to E. However, in this range of curing, the detrimental effect of the curing (i.e. going from E to B) is much greater for carbonation and chlorides, with the values increasing by about a factor of 2. In the case of the air permeability, the increase in this range of curing is by a factor in the range of 6 to 9.

The chloride and carbonation tests might be considered as a more direct estimate of the durability performance, whereas the strength is characterizing the mechanical behavior. The data here clearly indicates that durability performance is much more sensitive to the method of curing than strength. This highlights the common notion that estimate of the quality of concrete by strength measurement is not sufficient when durability is the issue to be concerned with.

The air permeability tests, which measures more directly the concrete cover properties, is clearly seen here to be more sensitive to curing effects, and can thus better reflect the durability performance, providing a much better estimate than strength. The torrent test method which was used here for determining air permeability was also found to be more friendly than other surface tests, and could lend itself to be more readily used on site [1/2].

Conclusions

1. Curing was found to affect durability performance to a much greater extent than its influence in strength. For example, deficient curing which resulted in about 20% strength reduction was accompanied by 100% increase in carbonation and chloride permeability.
2. This sensitivity to curing is expected to be reflected much more in the concrete cover, which is providing the durability protection. Thus, strength quality control will not be sufficiently effective to characterize this aspect of the concrete behavior.
3. The air permeability test, using the Torrent test method, was found to be sensitive to assess the influence of curing on the durability related parameters. In the range outlined in conclusion 1 the air permeability increased by more than 400%. In view of the fact that this test method is “friendly”, it has the

potential of providing a means for assessing the properties of the concrete cover with respect to durability performance, providing a much better indication than strength.

References

/1/ Proceq: Bedienungsanleitung TORRENT Permeability Tester. Proceq SA, Zürich, 2001

/2/ Torrent, R. ; Frenzer, G.: A method for the rapid determination of the coefficient of permeability of the covercrete. International Symposium Non-Destructive Testing in Civil Engineering (NDT-CE), Berlin 26.-28.09.1995

/3/ RILEM: Measurement of hardened concrete carbonation depth CPC 18. Materials and Constructions/Matériaux et Constructions, Vol 17, No 102

/4/ ASTM: ASTM C 1202-97, Standard Test Method for Electrical Indication of Concrete´s Ability to Resist Chloride Ion Penetration. Annual Book of ASTM Standards 1999, Volume 04.02 Concrete and Aggregates

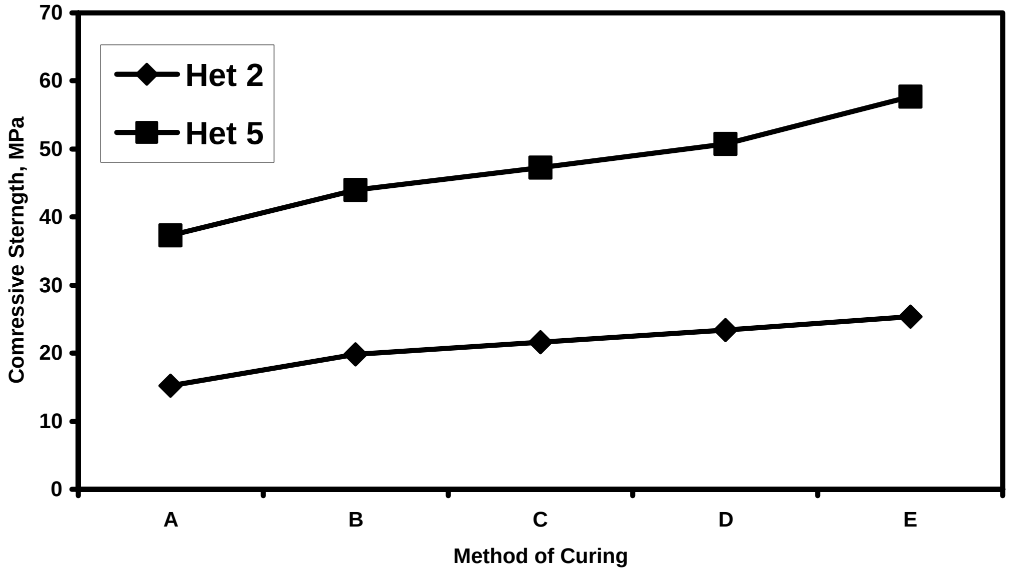

Figure 1: Influence of curing on 28 days compressive strength

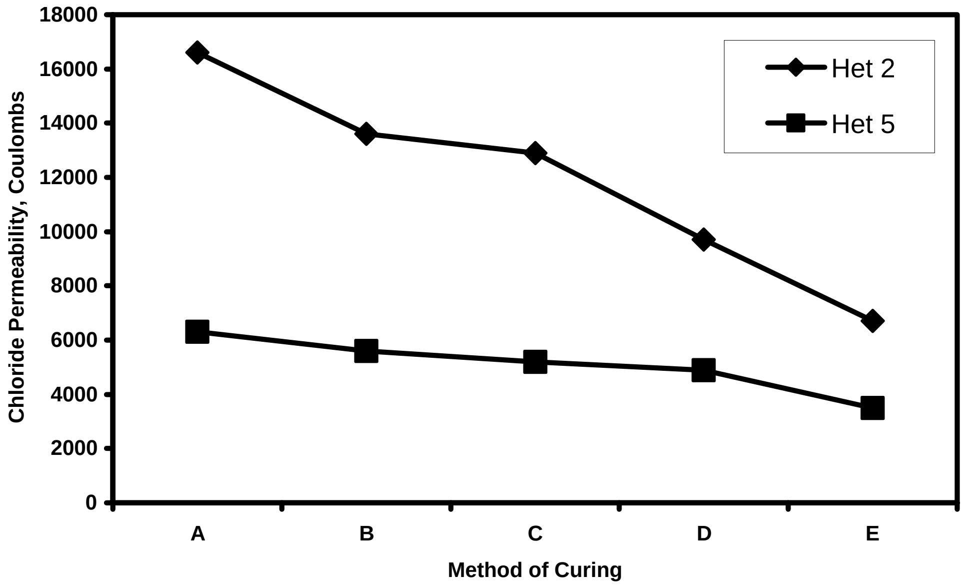

Figure 2: Influence of curing on chloride permeability

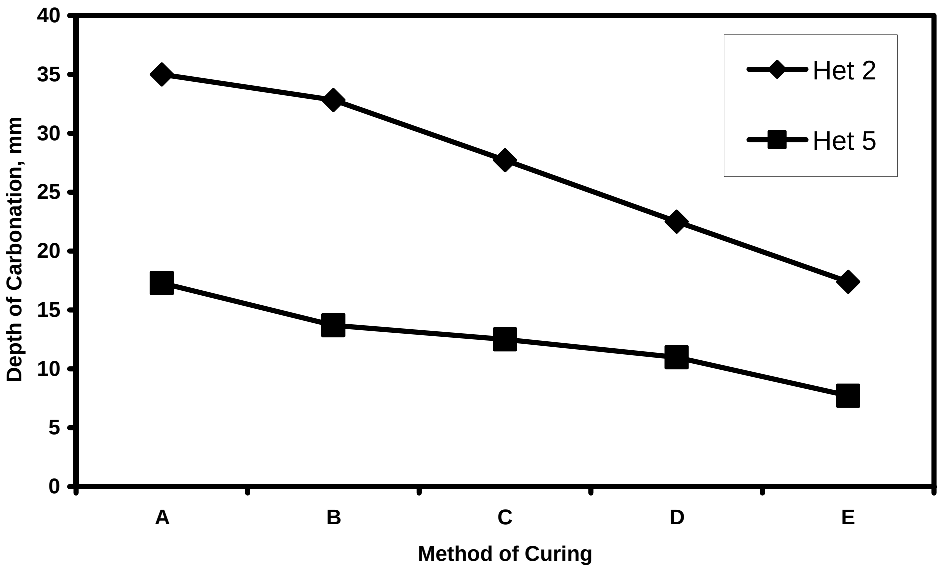

Figure 3: Influence of curing on depth of accelerated carbonation at 7 days

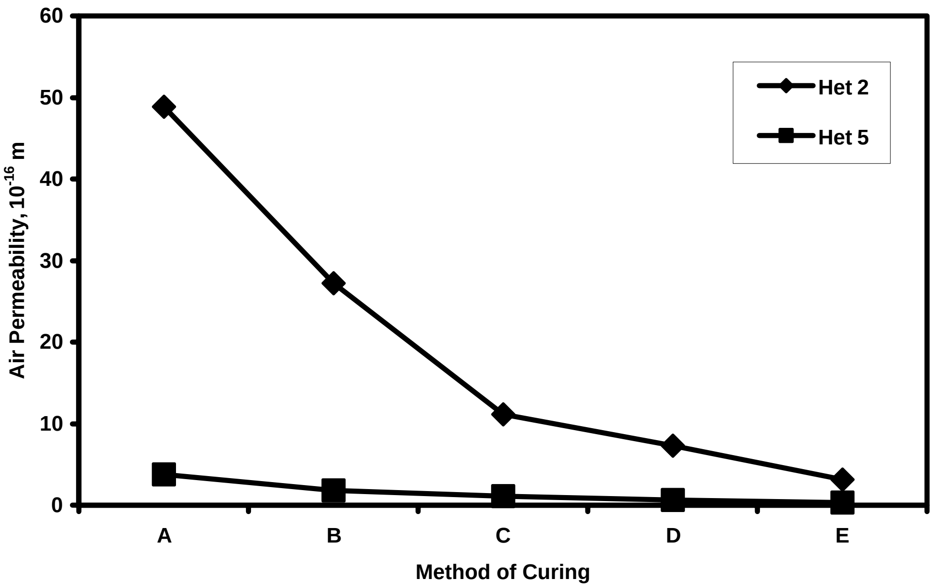

Figure 4: Influence of curing on air permeability

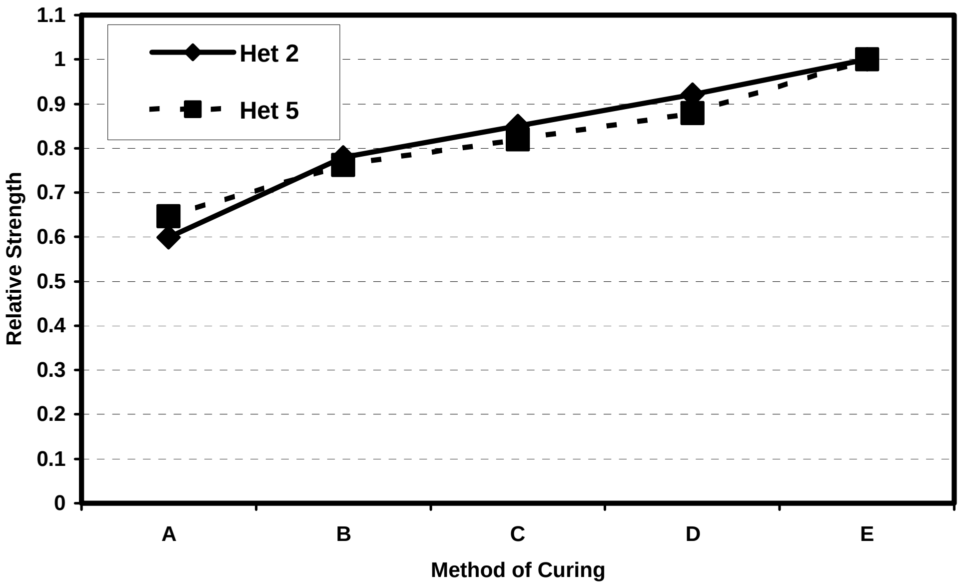

Figure 5: Influence of curing on relative 28 days compressive strength

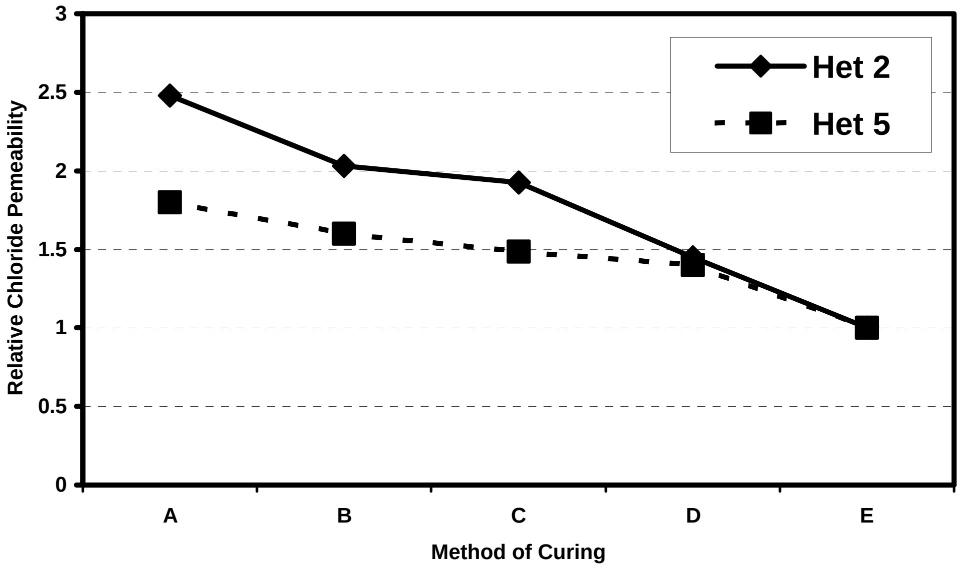

Figure 6: Influence of curing on relative chloride permeability

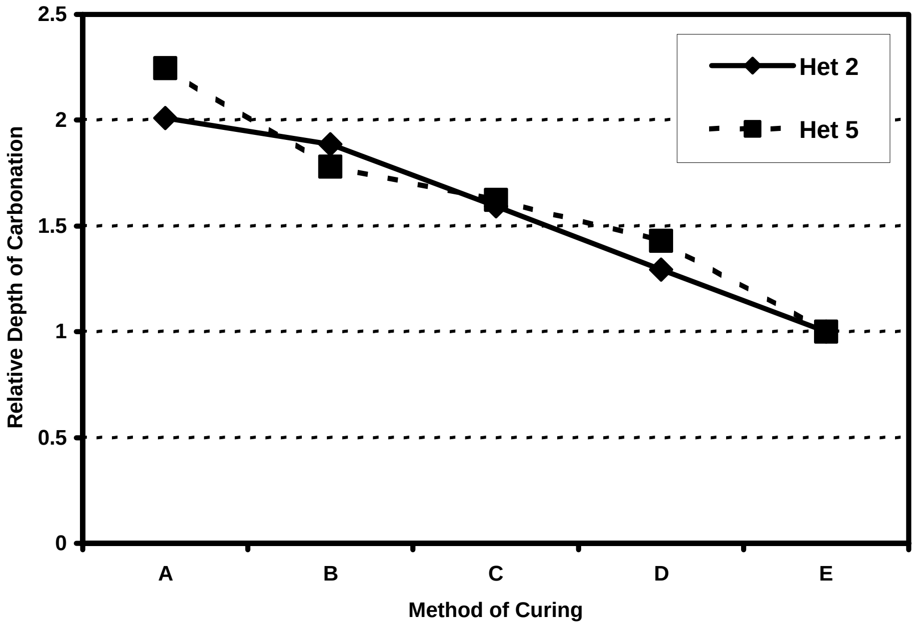

Figure 7: Influence of curing on relative depth of accelerated carbonation at 7 days

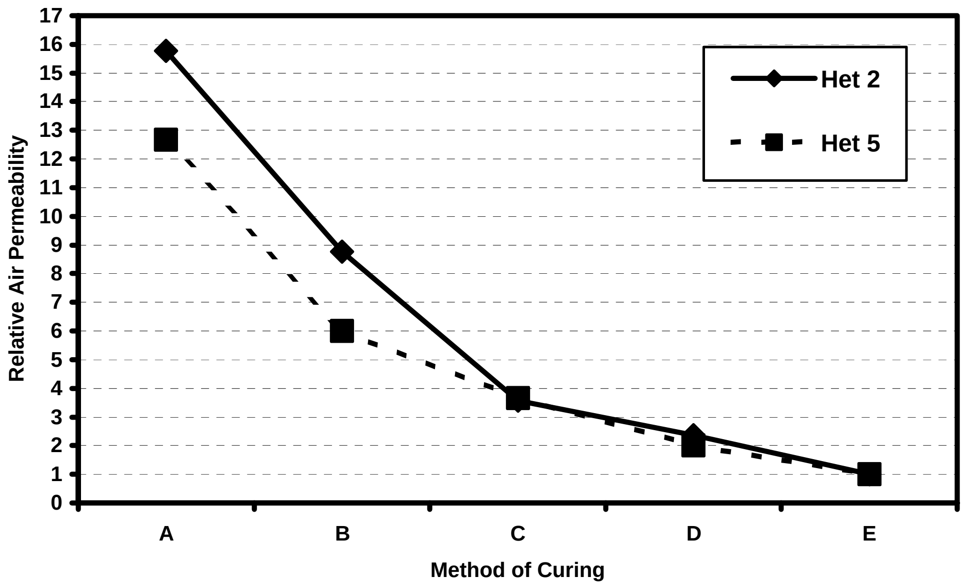

Figure 8: Influence of curing on relative air permeability