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RILEM TECHNICAL COMMITTEE

Update of the recommendation of RILEM TC 189-NEC 'Non-destructive evaluation of the concrete cover' "Comparative test—Part I—Comparative test of penetrability methods", Materials & Structures, v38, Dec 2005, pp. 895–906

RILEM Technical Committee*

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1 Object of this update

The original article presented a summary of the results and conclusions of a Comparative Test conducted within the scope of RILEM TC 189-NEC "Non destructive Evaluation of the Concrete Cover". The Comparative Test (CT) was intended to assess, under the same conditions, the performance of different non-destructive test (NDT) methods designed to measure the "penetrability" of the concrete cover on site.

The original article reflects accurately the situation at the date of publication.

In view of concerns expressed by one of the participants on the effect of the moisture content of the concrete, at the time of the tests, on the results obtained from one of the NDT methods, namely the Autoclam Permeability System, the analysis of the results was revised.

The aim of the present article is to update the results, presented in the original article, as a consequence of this revision.

For a full understanding of the present update, a reading in conjunction with the original article is recommended.

Alternatively, the reader is referred to Chapter 8 of RILEM Report 40: State-of-the-Art Report on Non-Destructive Evaluation of the Penetrability and Thickness of the Concrete Cover, by RILEM Technical Committee 189-NEC, (ISBN 978-2-35158-054-7), Eds. R. Torrent and L. Fernández Luco (2007) RILEM Publications S.A.R.L. That Chapter contains the full final report of the Comparative Test Part I—Comparative test of penetrability methods, including all recorded data.

2 Curing and pre-conditioning of the slabs

All slabs were initially stored in a moist room (20°C, 90% RH) for 24 h. Subsequently they were demoulded and treated as detailed below.

*This document has been prepared by R. Torrent chairman of the RILEM TC 189-NEC Committee that consists of 26 members representing 12 countries.

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- Sets 1–5 were kept in the moist room (20°C, 90% RH) until 7 days of age. Thereafter, the specimens were stored in a room at "Normal" ambient conditions (20°C, 70% RH) until testing.
- Set 6 was stored in a dry room (20°C, 35% RH) until 7 days of age. Thereafter, the specimens were kept in a room at "Normal" ambient conditions (20°C, 70% RH) until testing.
- The treatment of Sets 7 and 8 initially followed the same cycle as Sets 1–5. However, 7 days prior to commencement of the NDT tests the samples were immersed in water for 1 day and thereafter kept in a "Moist" room (20°C, 90% RH) until testing. Testing samples that were treated in this way simulated measurements carried out after rainfall in an environment of high relative humidity.
- The treatment of Sets 9 and 10 initially followed the same cycle as Sets 1–5. However, for a period of 7 days prior to commencement of the NDT tests (and during the tests) the samples were kept in a "Cold" room (10°C, RH not controlled). Testing samples that were treated in this way simulated measurements carried out in an environment of low ambient temperature.

The age of the slabs at the initiation of the NDT tests, that lasted 5 days, ranged between 54 and 69 days.

3 Conditions of the slabs when tested with NDT

In the planning of the experiment, a specific treatment of the slabs was agreed and rigorously observed. There was no target for the internal RH (i.e. moisture condition) of the slabs, so the resulting RH was a consequence of the agreed treatment. As a result of the different treatments, the concretes presented varying conditions of temperature and moisture at the time when the various "penetrability" tests were applied.

To have an indication of the temperature and moisture conditions of the concrete in the slabs for the different Test Conditions (at the date of the CT), measurements of Temperature and Relative Humidity were performed, both by LNEC (Portugal) and Queen's University Belfast (QUB, UK), inside drilled holes sealed to create a cavity, (35 and 10 mm deep, respectively). Table U.1 presents the results obtained.

As explained above, the planning of the experiment aimed at achieving special testing conditions for Sets 7 and 8 ("Moist") and for Sets 9 and 10 ("Cold").

From Table U.1 it is possible to confirm that the "Moist" and "Cold" conditions were actually achieved. Indeed, for Sets 7 and 8 the relative humidity measured in the concrete ranged between 90 and 92% (the temperature was close to 20°C). Similarly, for Sets 9 and 10, the temperature measured in the concrete was 10–11°C (the relative humidity ranged between 82 and 89%).

For Sets 1–6, tested under "Normal" conditions, the relative humidity of the concretes was within the range 78–85% and the temperature was close to 20°C.

As a result of these measurements, Table 1 of the original article should be replaced by Table U.2 (the main change being in the definition of the condition for Sets 1–6, referred now as "Normal" instead of "Dry", as presented in the original article).

4 Effect of the moisture conditions on the performance of the Autoclam Permeability System

As shown in Table U.1, almost invariably the relative humidity of the slabs exceeded 80%, even for those stored for almost 2 months under "Normal" ambient conditions (20°C, 70% RH). This put all NDT methods based on gas transport or water suction under rather challenging conditions.

In the particular case of the Autoclam Permeability System, it is important to highlight that its Operating Manual states "…it is recommended that tests are carried out when the concrete is relatively dry (i.e. when the internal relative humidity of the cover concrete up to a depth of 10 mm is less than 80%)."

Therefore, the results obtained in the CT with the Autoclam instrument must be taken with caution as they might have been affected by the fact that the RH of the concretes was almost invariably above 80%.

5 Correlation to Reference Tests

With the above limitation in mind, the performance of the Autoclam test was revised, in particular the

Table U.1 Temperature and relative humidity measured in the slabs

Test Condition	Room conditions	T [°C] of slab (QUB)	RH [%] of slab (QUB)	T [°C] of slab (LNEC)	RH [%] of slab (LNEC)
1	"Normal" T = 20°C RH = 70%	19.2	78.0	20.1	82.1
2		–	–	20.3	83.8
3		–	–	19.9	84.3
4		–	–	20.0	84.0
5		–	–	20.3	85.1
6		–	–	20.1	82.5
7	"Moist" T = 20°C RH = 90%	19.5	90.3	19.8	90.6
8		19.6	89.5	19.9	92.1
9	"Cold" T = 10°C	10.0	89.1	11.0	82.5
10		9.9	87.3	11.1	86.5

Table U.2 Test Conditions investigated in the experiment

Variable	Test Condition									
	1	2	3	4	5	6	7	8	9	10
w/c	0.40	0.55	0.60	0.40	0.55	0.55	0.40	0.55	0.40	0.55
Cement type	OPC	OPC	OPC	BFSC	BFSC	OPC	OPC	OPC	OPC	OPC
Moist curing (days)	7	7	7	7	7	1	7	7	7	7
Condition when NDT applied	"Normal"						"Moist"		"Cold"	

correlation of its results with Reference laboratory tests involving the same or similar "penetration" mechanism.

In the original article, on request of the participant who applied the Autoclam Permeability System, it was agreed that the correlations were made omitting for the calculation the test data corresponding to Sets 7–10, as they were clearly made on concretes with high RH (Fig. 1a and b of the original article).

A further revision of the data, including all Sets 1–10, revealed that the result corresponding to Set 3 falls completely out of the reasonable general trend of the results of the other 9 Sets.

Based on that, the correlations have been recalculated with the 10 results and also without the "outlier" result of Set 3.

The graphical regressions for the Autoclam Air Permeability Index, together with the correlation coefficients R, are presented in Fig. U.1a and b (the outlier result is marked with a circle). Therefore, Fig. U.1a and b should replace Fig. 1a and b of the original article, respectively.

As a consequence, the second paragraph of Sect. 5.2.1 of the original article (starting with "...Regarding correlation with the Reference Tests...") should be replaced by the following one:

"Regarding correlation with the reference tests, we can say that all three methods present excellent correlations with the RILEM-Cembureau O2-Permeability and also (albeit to a lesser extent) with the Water Absorption Reference Tests. An outlier was apparent in the results of Autoclam, indicating a possible underestimation of the permeability of the concrete with w/c = 0.60 (Test Condition 3), compared to the value obtained with the RILEM-Cembureau method. When this result is disregarded, the correlation coefficients are significantly improved."

A similar revision was conducted for the results of the Autoclam Water Sorptivity Index, with the results shown in Fig. U.2a and b. Figure U.2a should then replace Fig. 2a of the original article.

Regarding Fig. U.2b (identical to original Fig. 2b), the result for Set 3 does not depart from the general

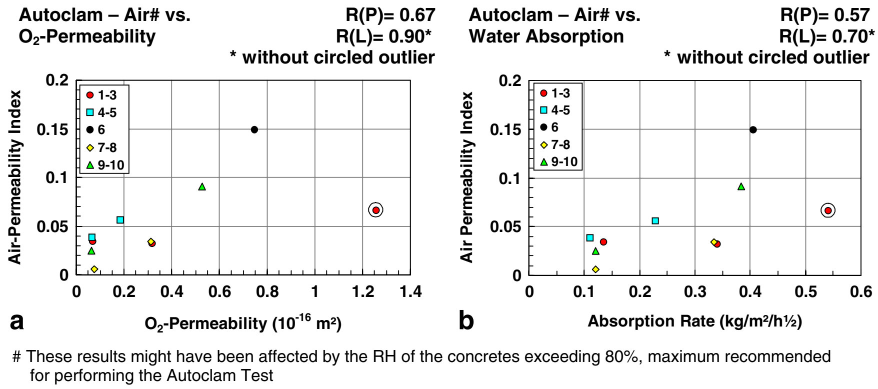

Fig. U.1 Correlation between Air Permeability Index and related Reference Tests

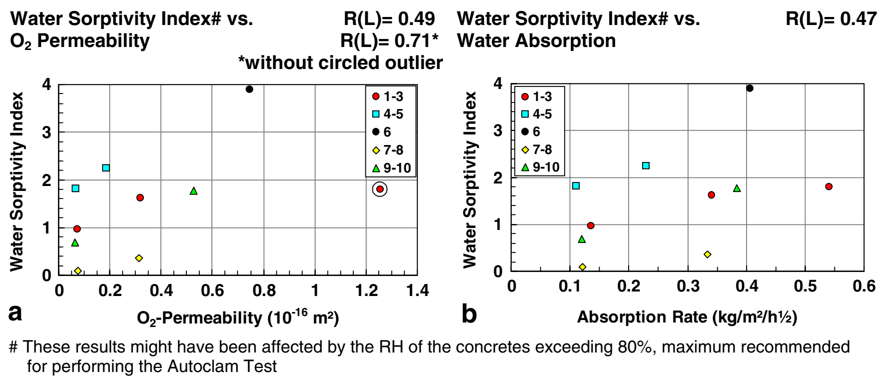

Fig. U.2 Correlation between Water Sorptivity Index and related Reference Tests

trend, hence the reason why only one correlation coefficient is reported, as in the original article.

6 Conclusions of the Comparative Test

The conclusions presented in Sect. 6 of the original article are repeated below; they remain identical with the exception that Table U.3 should replace the original Table 7.

"A summary of the quantitative recorded aspects of the performance of the test methods is presented in Table U.3.

It can be concluded that the Comparative Test at EMPA was well designed, planned and executed to provide meaningful and objective results. The fact that the testers involved, both on site and at the laboratories, did not know the identity of the slabs or cores they were testing, guarantees the objectivity of the results obtained.

Table U.3 Performance of the different NDT methods applied in the Comparative Test

Transport mechanism	Gas permeability			Water sorptivity	Electrical resistivity
Methods aspect	Autoclam air	Hong-Parrot	Torrent	Autoclam sorptivity	Wenner
Discrimination*	□□□□□□■■	□□□□□□□■	□□□□□□□□■	□□□□□□□□■	□□□□□□■■
Correlation coefficient R[a]	0.67 0.90[b]	0.92	0.97	0.47	0.83
Measurements per Test Condition	3	4	6	3	20
Duration per Test Condition (min)	69	120	99	69	14
Impact: no. of holes × diameter	9 × 6 mm	4 × 20 mm	0	9 × 6 mm	0

* □ = Significant or highly significant; ■ = Not significant or wrong

[a] With Reference Test for the same transport mechanism

[b] Without "outlier" result for Test Condition no. 3

Although to a varying degree, the Comparative Test proved that there are methods capable of evaluating the “penetrability” of the concrete cover on site, in a reliable and statistically significant manner. In five or six out of seven cases, the test methods were capable of detecting correctly the expected differences in “penetrability” at a significant or highly significant level. Moreover, some of the site methods showed very good correlations with corresponding relevant Reference Test methods.

This opens good perspectives for the application of such methods in practice, for the specification and “in situ” compliance control of the “penetrability” of the vital concrete cover, aiming at performance-oriented criteria regarding the durability of concrete structures.”