COMUNICAÇÃO TÉCNICA

Nº 179636

Investigation of concrete moiusture using no-destructive methods across diffeent compositions and expossure conditions

Lucas Clementino Nascimento
Adriana de Araujo
Valdecir Angelo Quarcioni

Palestra apresentada no INTERNATIONAL FIB SYIMPOSIUM ON CONCEPTUAL DESIGN OF STRUCTURES. 2025, Rio de Janeiro.13 slides.

International *fib* Symposium on Conceptual Design of Structures

Investigation of Concrete Moisture Using Non-Destructive Methods Across Different Compositions and Exposure Conditions

Lucas C do Nascimento, Adriana de Araujo and Valdecir A. Quarcioni

Technological Research Institute of the State of São Paulo - IPT

Organization

14-16 May 2025 I Rio de Janeiro, Brazil

INTRODUCTION

THE **DURABILITY** OF **ATMOSPHERIC STRUCTURES** IS STRONGLY INFLUENCED BY **MOISTURE CONTENT IN CONCRETE**

- ✓ **Moisture levels** are affected by **environmental conditions** and **exposure to water**;
- ✓ **Water** enables the **transport of harmful agents** into the concrete and **plays a key role in chemical reactions related to degradation of concrete and rebar corrosion.**

CONCRETE MOISTURE DETERMINATION:

✖ ✓ **Gravimetric Method (Lab):** Measures mass changes at different moisture states.

✓ **Embedded RH Electrode (ASTM F2170):** Measures moisture inside the concrete

✓ **Non-destructive test** (**NDT, lab** and **field**), such as equipment like:

✖ • **Moist 210B:** Uses **dielectric losses from microwave interaction** with water to **estimate moisture content;**

✖ • **Resipod:** use **Wenner method** to measure **electrical resistivity, indirectly indicating moisture content**.

OBJECTIVE OF THE STUDY

Comparative **analysis of the gravimetric method** and **two NDTs** (**Moist 210B** and **Resipod**), considering:

- ✓ ***Different concrete mixes;***
- ✓ ***Presence/ absence of carbonation;***
- ✓ ***Different moisture conditions.***

RESEARCH MOTIVATION:

Improve inspection practices, focusing on corrosion risk in reinforced concrete.

Analyze the impact of carbonation and ambient humidity on moisture content in concrete.

METHODS

- ✓ ***Different concrete composition:***
  - ***3 Mix :***

    CS: C260 – 260 kg/m³ of cement, w/c = 0.65

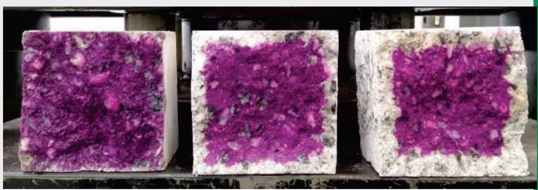
    CS: C300 – 300 kg/m³ of cement, w/c = 0.65

    CS: C360 – 360 kg/m³ of cement, w/c = 0.45

  - ***Portland cement: CPV-ARI*** *Plus (equivalent to* ***ASTM Type III****);*
  - ***Aggregates:*** *medium* ***quartz sand*** *and* ***crushed granite*** *(≤ 12.5 mm)*
  - ***Cylindrical concrete specimens (CS):*** Ø10 × 20 cm

✓ ***Carbonated front:***

- **dried CS for 14 days** (at 23 °C and 60% RH), **followed by exposure to a climate chamber** (23 °C, 60% RH, and **3% CO_2**). The carbonated **CS** were designated as '**C**';
- Prismatic **CS** for carbonation front evaluation



C360C	C300C	C260C
1 mm/ 36 weeks	10 mm/ 34 weeks	10 mm/ 18 weeks

✓ ***Different moisture conditions:***

- **CS: 100% RH**: saturating immersion in water;
- **CS: 90% and 70% RH**: climate chamber;
- **CS: Dried**: oven-drying (80 °C for 72 h).

CONCRETES TEST

Concrete CS	Condition	C_C (kg/m³)	w/c ratio	Compressive strength (28 days)	Density (g/cm³)	Capillary water absorption (g/cm²)	Porosity index (%)
C260	non-carbonated	260	0.65	37	2.53	1.03	11
C260C	Carbonated (10 mm)						
C300	non-carbonated	300	0.58	45	2.52	0.87	10
C300C	Carbonated (10 mm)						
C360	non-carbonated	360	0.45	55	2.54	0.56	8
C360C	Carbonated (1 mm)						

✓ *Method and equipment:*

GRAVIMETRIC METHOD

Weighing each **CS** after establishing the moisture condition

*Moisture Content (**MC, %**):*

$$MC = \frac{m_w - m_d}{m_d \times 100}$$

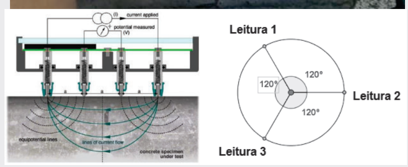
m_w = mass of the concrete specimen under a specific moisture condition (kg)
m_d = oven-dry mass at 80 °C (kg)

NDT- MOISTURE CONTENT (Moist 210B)

Performed on top and base of each **CS**

NDT - ELECTRIC RESISTIVITY (Resipod)

3 measurements (120^0) in each **CS**

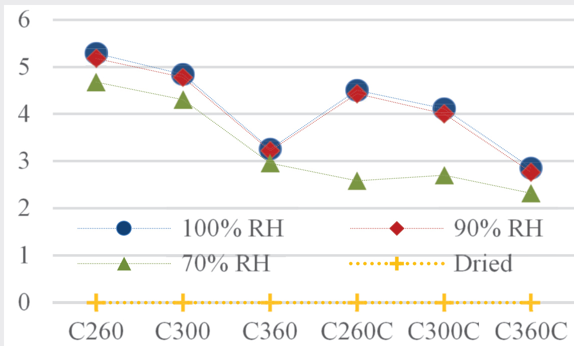


RESULTS - GRAVIMETRIC METHOD

Moisture content (*MC*) values obtained in the **gravimetric method**

- ***Cement Content Effect:***
  Higher cement content → **Lower detected MC** (denser microstructure, reduced porosity);
- **Carbonation Effect**:
  Carbonation → **Decrease** in **MC**;
- **Relative Humidity Transition to 100% → 90%**:
  No **significant change** in **MC**.

*Moisture Content (**MC, %**):*



RESULTS - Moist 210B and Resipod

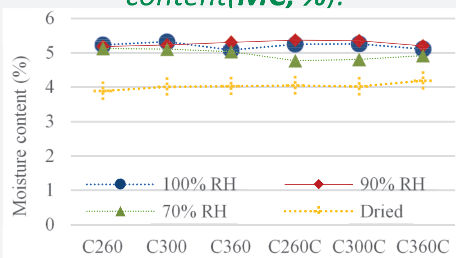
Dry Condition:

- **Moist 210B:** Detects residual **MC** in all concretes.
- **Resipod:** Does not register surface resistivity.

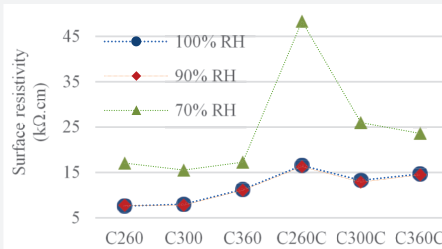
Dry vs. Other Conditions:

- **Moist 210B: Clearly separates dry state from other conditions**, with **similar MC across the concretes**.
At 70% RH, **carbonated concretes** (C260C and C300C) show **slightly lower MC**.
- **Resipod:** *At 100% and 90% RH*: **lower quality concretes** (C260 and C300) **show lower resistivity**. **Carbonation increases resistivity, making values similar**.
At 70% RH, **resistivity is similar across concretes, increasing with carbonation, especially for low quality** (C260C).

***Moist 210B** – moisture content(**MC, %**):*



***Resipod** – Resistivity (kΩ.cm):*



CONCLUSIONS

Joint Analysis – Gravimetric, Moist 210B (NDT), and Resipod (NDT):

All three methods captured moisture variations and the effects of carbonation. ANOVA revealed a significant correlation between the moisture content measured by the Moist 210B (NDT) and the gravimetric method.

Only the **Moist 210B** detected residual moisture in dried concrete, showing higher sensitivity to bound water. In contrast, the **Resipod** (NDT) showed limitations under low-moisture conditions.

The **Resipod** effectively detected carbonation effects, with a greater resistivity increase in lower-quality concrete, indicating a stronger impact in more porous materials.

Concrete quality and the effect of carbonation:

Higher-quality concrete **exhibited lower moisture content** and **higher resistivity**, reflecting a denser and less porous microstructure. **This trend was more clearly seen through the 70% RH measurements.**

Carbonation caused a **decrease** in **moisture content** (detected by both gravimetric and Moist 210B) and an **increase in resistivity** (Resipod), attributed to pore refinement and blockage. The **resistivity increase was most pronounced in carbonated concrete with lower quality,** suggesting that carbonation can partially compensate for initial microstructural deficiencies.

Thank You

Lucas C do Nascimento, lucascn@ipt.br
Adriana de Araujo, aaraujo@ipt.br
Valdecir A. Quarcioni, quarciva@ipt.br

ipt

Technological Research Institute of the State of São Paulo

International *fib* Symposium on Conceptual Design of Structures
Rio de Janeiro 2025

fib CEB-FIP Young Members Group

Organization

ASSOCIAÇÃO BRASILEIRA DE ENGENHARIA E CONSULTORIA ESTRUTURAL ABECE

Abcic Associação Brasileira da Construção Industrializada de Concreto

ABPE Associação Brasileira de Pontes e Estruturas

fib CEB-FIP