GPR detection of saturated areas into concrete in the presence of a water gradient

Louis A., Van der Wielen A., Courard L., Nguyen F.

University of Liege — GeMMe

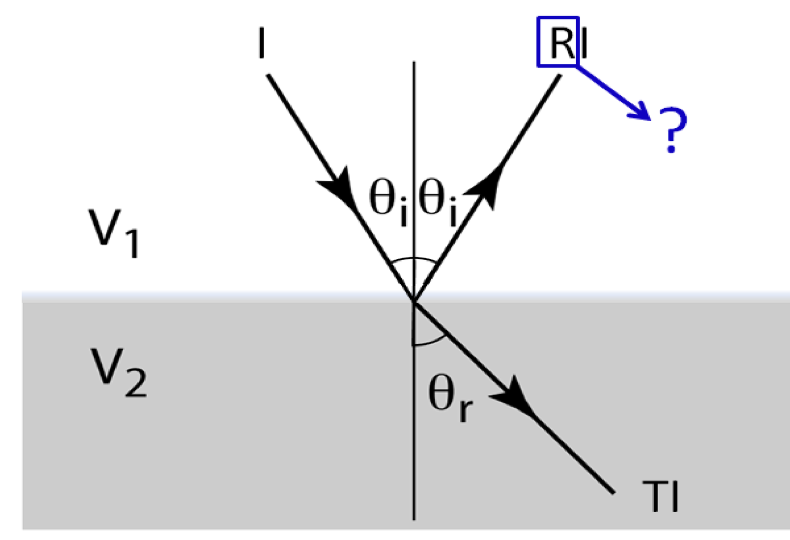
Introduction

The concrete can be aggressed by diverse degradation mechanisms. Almost all concrete pathologies needs water for developing. The humid zones, into a concrete structure, are thus indicators of potentially degraded zones. The use of Ground Penetrating Radar (GPR) for the detection of humid zones is possible because the concrete dielectric properties are highly dependent on its water content. In this context, the radar can be used as an efficient nondestructive technique to detect future problems within concrete structures.

Theoretically, a sharp interface between materials presenting different dielectric properties can be easily detected by the GPR. But the humid zones are most of the time surrounded by a zone presenting a water gradient. This gradient zone is likely to modify the measured radar signal. More specially, one may ask: "what's the influence of this gradient on the reflection coefficient R?"

Example of degradation on a bridge deck slab

(modified from Demars, 2011)



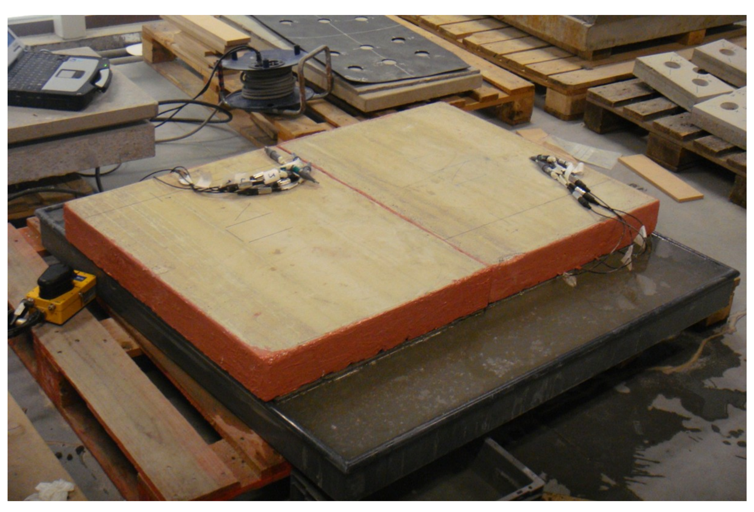
Reflection coefficient (R) between two interfaces separated by a gradual evolution of dielectric properties

(modified from Giroux, 2005)

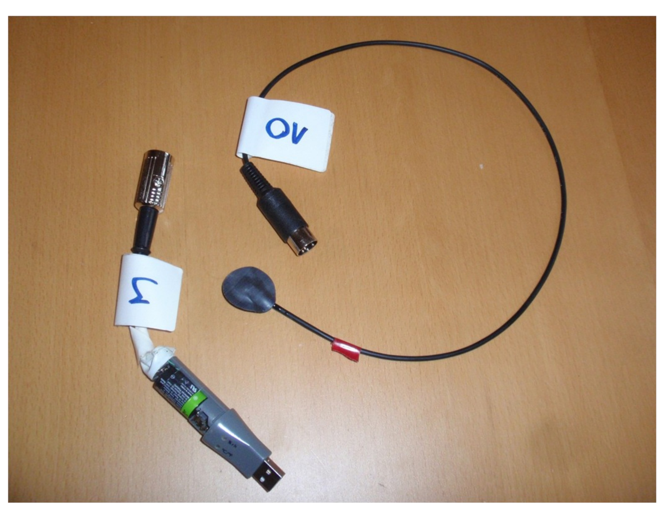
Experimental program

Various finite difference simulations were performed using the program GprMax2D. GprMax is a finite difference time domain (FDTD) program allowing to simulate the propagation of electromagnetic waves and, in particular, of GPR waves. Whit this program, the influences of the gradient size between two slabs were studied (thickness variation between 0 and 5 cm).

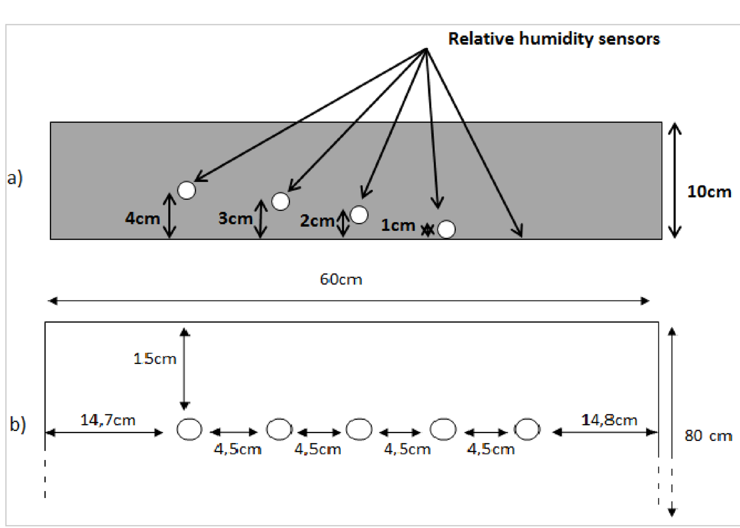
In the second phase of the project, we tried to create a controlled gradient in a concrete slab, using the simple capillary rise principle. To control the evolution of the gradient, we inserted hygrometric sensors into the slab. A correlation between this gradient evolution and the results provided by a Ground Penetrating Radar with a 2.3 GHz antenna has been studied. We have highlighted the influence of the gradient on the temporal evolution of the received electromagnetic field.



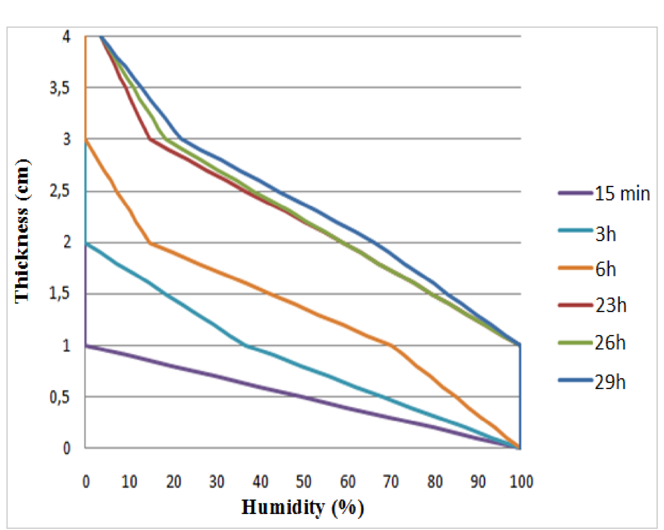
Experimental setup



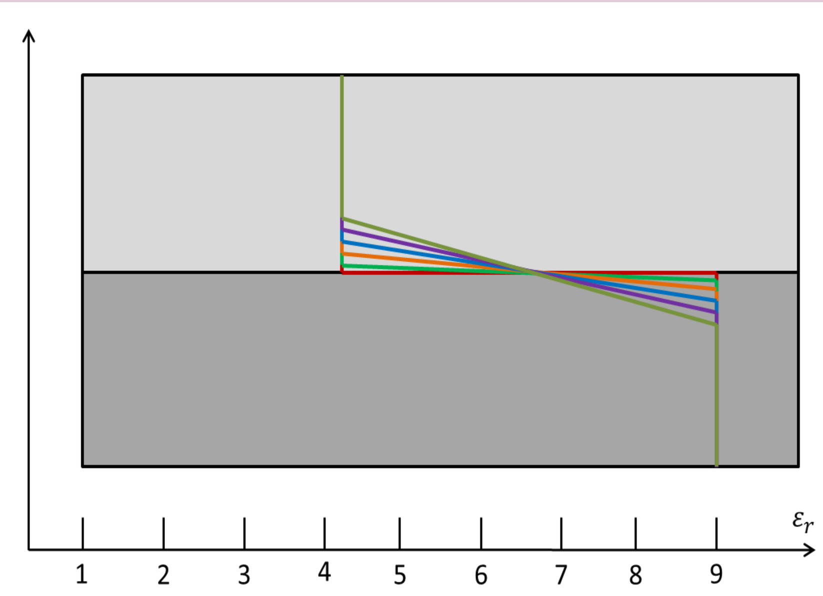
Hygrometric sensor before introduction into concrete



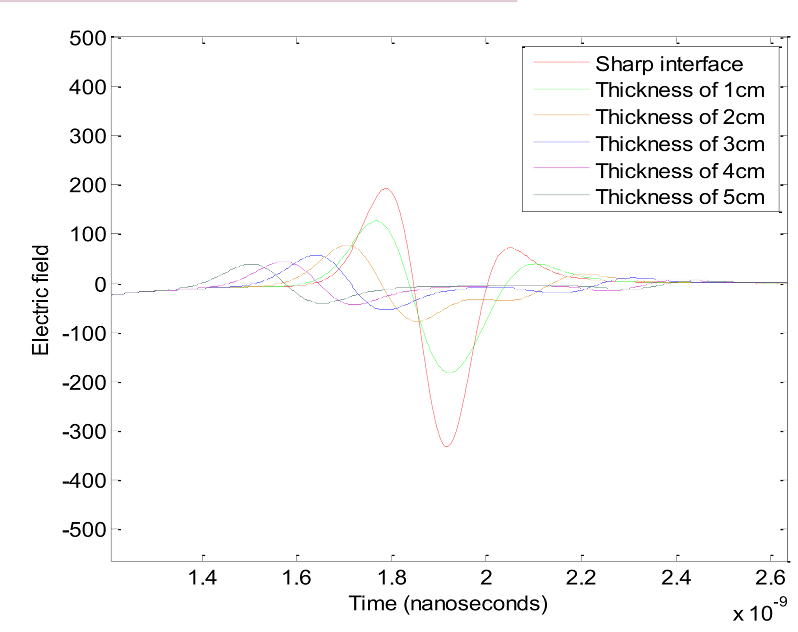
Vertical (a) and lateral (b) position of sensors



Processed moisture profile obtained into slab by the hygrometric sensor



Evolution of the permittivity into the slabs (modeling)

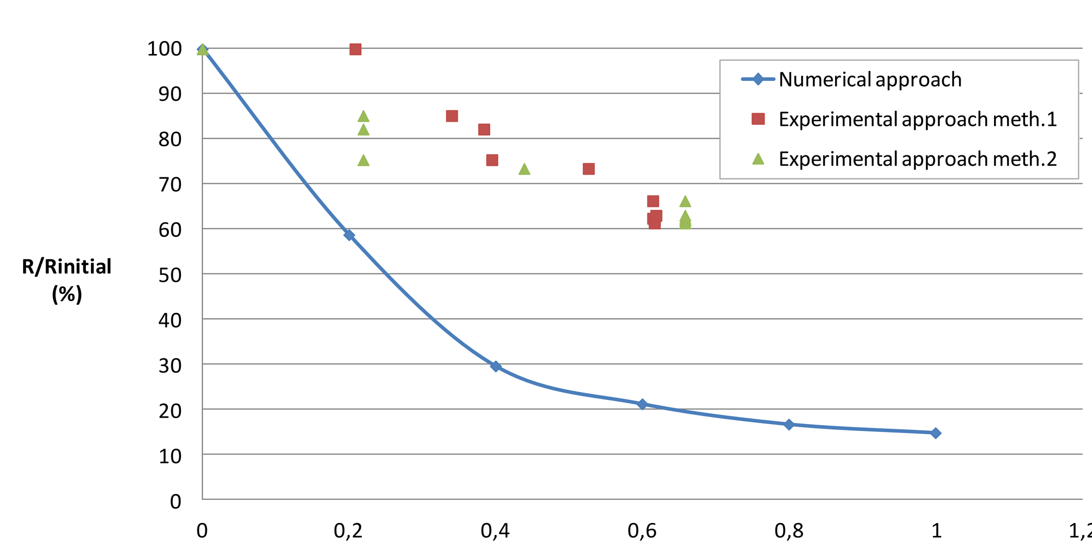


Evolution of the electric field reflected on the interface between the two slabs versus the transition zone thickness.

Results & Conclusions

In both approaches, we were able to demonstrate a decrease of the reflection amplitude when the thickness of the transition zone increases. In the numerical approach, this decrease is very fast and gradually tends to stabilize. In the experimental approach, we didn't observe the nonlinear evolution of the amplitude but the decrease of the values remained clearly visible. The experimental values were expected to be higher than numerical value because the numerical approach with a linear permittivity variation gives a lower limit.

We can therefore conclude that the detection of humid zone in the concrete is a complex problem: the moisture gradient surrounding the humid zone doesn't prevent its detection but makes it more difficult. The wavelength of the signal and the thickness of the transition zone are the two important parameters which determine the visibility of the humid zone. If the thickness of the transition zone is beyond 0.4 to 0.5 times the wavelength, the reflection coefficient significantly decreases.



The reflection amplitude decreases with the increase of the transition zone thickness

References

- *A. Louis, "detection of wet areas in concrete presenting a humidity gradient by ground penetrating radar (GPR)", master thesis, Université de Liège, Liège, 178p, 2011 (in french).*
- Giroux B. 2005. Geological radar. *In : High resolution techniques for geophysique* [slides]. Montreal,

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