# PhD Proposal 2017

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| **School: Ecole Centrale de Nantes** | |
| **Laboratory: GeM UMR-CNRS 6183** | **Web site: https://gem.ec-nantes.fr/** |
| **Team: MEO (Materials- Environment - Structures)** | **Head of the team: Prof. Ahmed LOUKILI** |
| **Supervisor: Prof. Frédéric GRONDIN** | **Email: frederic.grondin@ec-nantes.fr** |
| **Collaboration with other partner during this PhD:**<br>**In France: Prof. Ahmed LOUKILI (GeM, ECN), Prof. Mazen SAAD (Lab. Jean Leray, ECN)** | **In China:** |

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| **Title: Dynamic effect in the capillary pressure and on the desiccation of cement-based materials: impacts on the delayed strains** |
| **Scientific field: civil engineering** |
| **Key words: cement-based materials, mathematical modeling, porous mechanics, experiments, micromechanics, off-shore structures, dynamic capillary pressure** |

**Details for the subject:**

*(Maximal length of 2 pages, including images, list of reference, …The pdf file should not exceed 1Mo)*

**Background, Context:**

**Offshore and marine structures are submitted to severe environmental conditions. For reinforced concrete structures the degradation occur due to several reasons: the infiltration of aggressive ions (chloride, sulfate, etc.) in the concrete's porosity causing chemical reactions and damage (Rozière et al., 2009), repeated wetting-drying cycles causing significant swelling and shrinkage phenomena which lead to cracks in the cement matrix, corrosion of the reinforcement, etc. To predict these risks, experimental procedures and highly sophisticated models have been developed by researchers around the world:**

**- experiments help define probabilistic laws to predict the risk,**

**- models try to approach real phenomena based on physical relationships.**

**These models often require calibrated parameters adjusted on the experimental results. In the case of wetting-drying cycles, the differences observed between the numerical and experimental results can be explained by a phenomenon little known: the dynamic effect on the capillary pressure (difference between the pressure of the water and that of the interstitial gas in the pores of the cement matrix). Indeed, in the case of a rapid wetting and drying, water movements result in a rapid change in the capillary pressure. The models used until now to predict the drying of marine structures are based on the quasi-static behavior laws and totally neglect the dynamic effects. By-also known as capillary pressure is the main cause of delayed deformations (shrinkage) in the concrete. These deformations are often the cause of the occurrence of micro-cracks and must be mastered. Recent research has allowed offering capillary pressure law taking into account the dynamic effects (Hassanizadeh et al., 2002; Dahle et al., 2005; R. Helmig et al., 2007; Abidoye LK et al, 2014) but are not yet adapted to cementitious materials.**

**Research subject, work plan:**

**This work aims to develop models to predict the durability of structures in the marine environment, such as floating turbines. The Ecole Centrale de Nantes is carrying an ambitious project for the manufacture of floating wind turbines, the first European model will be at sea off the French coast (a few kilometers from Nantes) in a few months. The study of concrete constituting the flotation chamber is important for predicting the durability of the structure. In addition, the region where Nantes is located has many kilometers of coastline with concrete structures undergoing sea water cycles.**

**To propose a new model to predict the risk of cracking due to delayed strains of marine reinforced concrete structures, the proposed research work concerns two developments:**

**- An experiment to reproduce the dynamic effects due to drying and wetting in porous media.**

**- A multi-scale model taking into account the dynamic capillary pressure laws and fluid diffusion laws to simulate wetting and drying in cementitious materials.**

**The lab GeM developed over several years of original devices for studying complex phenomena in cementitious materials. Work has already been made in the laboratory to understand the wetting-drying cycles of marine concrete, but in quasi-static conditions. In this thesis, it is requested to develop a new experimental procedure, based on the experience of the laboratory, taking into account dynamic effects on the fluid diffusion. A porous material model will be proposed to calibrate the device. Then applications will be conducted on concrete commonly used in the marine environment.**

**At the same time, the dynamic behavior laws for the capillary pressure will be implemented in a finite element code by coupling them to a mechanical model for simulating delayed deformations. These models predict the shrinkage and creep deformations those of cementitious materials, as well as damage (Saliba et al., 2013). This new poro-mechanical model dynamics will be validated by experimental testing of the future system and applications on reinforced concrete structures will be carried out to predict the long term behavior of offshore structures and sea.**

## References:


Rozière, E., Loukili, A., El Hachem, R. and Grondin, F., **Durability of concrete exposed to leaching and external sulphate attacks**, Cement and Concrete Research (2009), 39(12), p. 1188-1198.

Hassanizadeh, S. M., Celia, M. A., & Dahle, H. K. (2002). **Dynamic effect in the capillary pressure–saturation relationship and its impacts on unsaturated flow**. *Vadose Zone Journal*, *1*(1), p. 38-57.

R. Helmig, A. Weiss, B. I. Wohlmuth, **Dynamic capillary effects in heterogeneous porous media**. Comput Geosci (2007) 11, p. 261–274

L. K. Abidoye, D. B. Das, **Scale dependent dynamic capillary pressure effect for two-phase flow in porous media.** Advances in Water Resources (2014), 74, p. 212–230

H. K. DAHLE, M. A. CELIA, S. M. HASSANIZADEH, **Bundle-of-Tubes Model for Calculating Dynamic Effects in the Capillary-Pressure-Saturation Relationship.** Transp. Porous Med (2005), 58, p. 5–22.

Saliba, J., Grondin, F., Matallah, M., Loukili, A. and Boussa, H., **Relevance of a mesoscopic modeling for the coupling between creep and damage in concrete**, Mechanics of Time-Dependent Materials (2013), 17(3), p. 481-499.