Ph.D. Candidate

Razieh Enjilela

Graduate Academic Unit

Physics

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July 15, 2020

10:0 a.m. (Atlantic)

Virtual Defence

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Examining Board:
Dr. Ben Newling (Physics)
Dr. Igor Mastikhin (Physics)
Dr. Michael Thomas (Civil Engineering)
Dr. Bruce Balcom (Physics) Supervisor

External Examiner: Dr. Tito José Bonagamba
Institute of Physics
University of São Paulo - Brazil

The Oral Examination will be chaired by:
Dr. Sasha Mullally, Associate Dean of Graduate Studies

BIOGRAPHY

Universities attended (with dates & degrees obtained):
2013 – present PhD candidate, University of New Brunswick
2005 – 2008 Master's Student, Campus of Azad University, Karaj, Tehran, Iran
2001 – 2005 Bachelor of Science, Karaj Campus of Azad University, Karaj, Tehran, Iran

Patents:
MacMillan, B., Balcom, B. J., **Enjilela, R**., US Provisional Patent (US62/881,705): "Methods and apparatus for T_1-T_2^* relaxation correlation magnetic resonance measurement of materials" filed August 1, 2019.

Publications:
[1] **Enjilela R.**, MacMillan B., Marica F., Afrough A., Balcom B.J., T_1-T_2^* Relaxation correlation measurements, Submitted to Journal of Magnetic Resonance, Revised in response to reviews.
[2] **Enjilela R.**, MacMillan B., McAloon M.J., Petrov O.V., Vashaee S., Balcom B.J. Controlling susceptibility mismatch effects, signal lifetimes, and SNR through variation of B_0 in MRI of rock core plugs, Journal of Magnetic Resonance (2019) 307, 106575.
[3] Merz S., Balcom B.J., **Enjilela R.**, Vanderborght J., Rothfuss Y., Vereecken H. and Pohlmeier A., Magnetic resonance monitoring and numerical modeling of soil moisture during evaporation, Vadose Zone Journal (2018)17:160099.
[4] **Enjilela, R.**, Cano-Barrita P.F de J., Komar A., Boyd A.J., Balcom B.J. Wet front penetration with unsteady state wicking in mortar studied by Magnetic Resonance Imaging (MRI), Materials and Structures (2018)51:16.
[5] Vashaee S., Li M., MacMillan B., **Enjilela R.**, Green D., Marcia F., Balcom B.J., Magnetic resonance imaging with a variable field superconducting magnet that can be rotated for vertical or horizontal operation, International Symposium of the Society of Core Analysts, Vienna, Austria (2017), August 28-31.
[6] **Enjilela R.**, Cano-Barrita P.F de J., Komar A., Boyd A.J., and Balcom B. J. Monitoring steady state moisture distribution during wick action in mortar by Magnetic Resonance Imaging (MRI), Materials and Structures (2017) 50:151.
[7] Merz S., Pohlmeier A., Balcom B.J., **Enjilela R.**, and Vereecken H., Drying of a natural soil under evaporative conditions: A comparison of different magnetic resonance methods, Applied Magnetic Resonance (2016) 47, 121-138.

Selected Conference Presentations:
[1] **Enjilela R.**, Cano-Barrita P. F. de J., Komar A., Boyd A.J., Balcom B.J., Wet front penetration with unsteady state wicking in mortar studied by MRI, International Conference on Magnetic Resonance Microscopy (ICMRM), August 13-17, 2017, Halifax, Nova Scotia, Canada.
[2] **Enjilela R.**, MacMillan B., Vashaee S., and Bruce J. Balcom, Magnetic resonance imaging with a variable field magnet, variation of B_0 to control sensitivity and susceptibility mismatch effects, International Conference on Magnetic Resonance Microscopy (ICMRM), August 13-17, 2017, Halifax, Nova Scotia, Canada.
[3] **Enjilela R.**, Cano-Barrita P. F. de J., Komar A., Boyd A.J., Balcom B.J., Monitoring steady state moisture distribution during wick action in mortar by MRI, 13th International Conference on Magnetic Resonance in Porous Media (MRPM), September 4-8, 2016, Bologna, Italy.

Magnetic Resonance and Magnetic Resonance Imaging Measurements of Porous Media: Fluid Quantification and Magnetic Susceptibility Contrast

<u>Abstract</u>

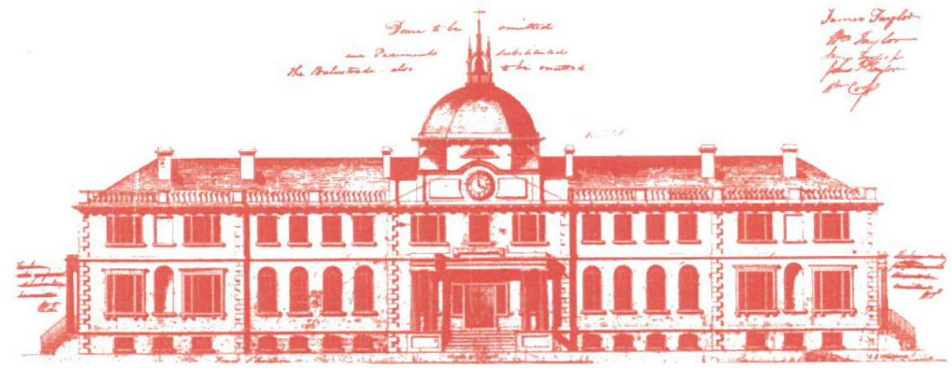
Magnetic Resonance (MR) and Magnetic Resonance Imaging (MRI) are non-destructive and non-invasive techniques that have been employed to study fluid content in porous materials such as core plugs and cementitious materials. Quantitative imaging of fluid content in porous media is an essential factor in MRI of such systems.

Water is intimately involved in the deterioration of structures built with cementitious materials. Quantitative moisture profiles may be acquired in porous media with SPRITE since its local image intensity has simple T_2^* contrast. In this thesis, MRI studies of unsteady and steady state moisture penetration due to wick action in mortar specimens are presented. The observed MR/MRI signal from mortar samples originated from two water populations, each with different signal characteristics. The interlayer water was spatially resolved for the first time in this work. Water in the pore space is more commonly observed in MR studies. The transport parameters controlling wick action were determined by fitting the moisture profiles through inverse modeling of one-dimensional moisture content profiles with the 1D Hydrus program.

Bulk T_1-T_2^* measurement was introduced in this thesis. The T_1-T_2^* measurement is a useful analog to the T_1-T_2 experiment. It is particularly important when an echo-based measurement is challenging due to short T_2 lifetime. Our previous studies on mortar suggested such samples would be ideal for T_1-T_2^* measurement. Monitoring changes of the T_1-T_2^* coordinate and associated signal revealed information about structural change in the samples under study.

In fluid bearing porous media, like cementitious materials and reservoir rocks, magnetic susceptibility mismatch between the matrix and pore fluids has a significant effect on the transverse MR signal lifetimes. These effects may be controlled through choice of the static magnetic field B_0.

An optimal field B_0 was predicted for SPRITE measurement of porous rock cores considering the linear relation between $1/T_2^*$ and B_0. Depending on the noise regime of the measurement, the maximum SNR may be readily predicted. A new style variable field magnet permits one to vary the field to control sample magnetization and to control the effect of magnetic susceptibility on the signal lifetimes in MRI of core plugs.



Home of the School of Graduate Studies, Sir Howard Douglas Hall was designed by J.E. Woolford in 1825 and is the oldest university building in Canada still in use.

The University of New Brunswick recognizes that the university sits on traditional Wolastoqey territory. The river that runs right by our university – the St. John River – is also known as Wolastoq, along which live the Wolastoqiyik -- the people of the beautiful and bountiful river.

UNIVERSITY OF NEW BRUNSWICK
SCHOOL OF GRADUATE STUDIES

ORAL EXAMINATION

Razieh Enjilela

IN PARTIAL FULFILMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY