

College of Arts and Sciences
PhD in Materials Science and Engineering

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Dissertation: Seismic Performance of FRP-Strengthened RC Beam-Column Joints Cast with Sustainable Cementitious Materials

Supervisors: Dr. Jamal A. Abdalla and Dr. Rami Antoun Hawileh

Abstract

This study aims to comprehensively assess the behavior of reinforced beam-column joints under reversed cyclic loading. The investigation included testing of 43 specimens with varying parameters, namely, the replacement percentages of Ordinary Portland Cement (OPC) with ground granulated blast slag (GGBS) and microsilia (MS), reinforcement arrangements within the joints, beam-column joint orientation as concentric and eccentric, over-strength ratio and the impact of strengthening using carbon fiber-reinforced polymer (CFRP) composites. All specimens were carefully instrumented to capture the impact of each parameter, and a detailed analysis of failure modes were conducted to ensure optimal outcomes.

Key seismic response characteristics, including ultimate strength, energy dissipation, ductility, stiffness, specific damping capacity and crack patterns, were analyzed to study the structural behavior of the joints. The study explored the correlation between concentric and eccentric joint arrangements, the effectiveness of strengthening using CFRP composites, and the influence of varying steel reinforcement bar configurations within the joint. The experimental results were utilized to develop an empirical model, which was validated against the experimental data to accurately predict the seismic performance of GGBS-MS reinforced concrete beam-column joints strengthened with CFRP. The empirical model provided a basis for recommendations and design guidelines considering over-strength ratio, material properties and joint configurations for estimating the overall seismic performance of beam-column joints with variable parameters considered in this study.

Vinod Paul

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Dissertation: Ultrasound-Triggered and Targeted Combination Therapy: Inhibiting Angiogenesis and Inducing Cytotoxicity in Colorectal Cancer

Supervisor: Dr. Ghaleb Adnan Ghaleb Husseini

Abstract

Liposome-based nanodrug delivery systems offer a promising strategy to mitigate the side effects associated with conventional chemotherapy. Tumor growth and progression are regulated by multiple pathways, which are often inadequately addressed by single-agent therapies. To overcome this limitation, combinatorial approaches employing multiple therapeutics have gained increasing attention.

In this study, a multifunctional liposomal formulation was developed that co-encapsulated regorafenib and 5-fluorouracil and was further functionalized with ramucirumab for active targeting. Liposomes were prepared by the thin-film hydration method, yielding uniformly sized vesicles below 200 nm that were stable at 4 °C and at room temperature. Encapsulation efficiency of regorafenib was optimized by varying cholesterol molar ratios, and drug content was quantified using UV-Vis spectroscopy and high-performance liquid chromatography (HPLC). The functionalized liposomes were designed to bind vascular endothelial growth factor receptors (VEGFR), which are overexpressed on endothelial cells in the tumor microenvironment, thereby enhancing site-specific drug delivery. The dual-drug system exhibited synergistic cytotoxicity against HCT116 colorectal cancer cells, with regorafenib providing broad-spectrum inhibition of angiogenesis and tumor proliferation. Ultrasound-triggered release further enabled temporal control over drug delivery. Tube formation assays demonstrated that the combination of ramucirumab and regorafenib effectively disrupted angiogenesis. Sonosensitivity of the liposomes was confirmed by encapsulating calcein and monitoring its release under 20 kHz ultrasound at varying power densities. Additional stability studies indicated minimal leakage of the encapsulated drug at 37 °C and enhanced release at 42 °C. Overall, the synthesized multifunctional liposomal platform integrates targeted delivery, combinatorial therapy and ultrasound responsiveness.



Mohammad Hani Yousuf

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Dissertation: 4D Printing of Remotely Activated Shape Memory Polymer Structures

Supervisors: Dr. Wael Abuzaid and Dr. Maen Abdelqader Al-Khader

Abstract

4D printing integrates smart materials such as shape memory polymers (SMPs) into additive manufacturing, enabling complex geometries capable of changing shape and properties upon thermal activation. However, intrinsic thermoplastic SMPs lack magnetic or electrical functionality, requiring direct heat exposure for activation, which limits their use in critical engineering applications. To overcome this limitation, magnetic or electrical properties can be introduced to enable remote activation through induction heating or Joule heating.

Accordingly, this work explores two innovative methods to achieve remote activation of 4D printed thermoplastic SMPs. The first approach introduces magnetic functionality through the incorporation of the semi-metallic manganite $\text{La}_{1-x}\text{Sr}_x\text{MnO}_3$ (LSMO) into the SMP matrix via solution mixing. The resulting magnetic nanocomposite demonstrated comparable shape memory performance to plain SMP along with enhanced mechanical properties. The second approach eliminates the need for conductive nanofillers by embedding conductive thermoplastic polyurethane (cTPU) pathways within the SMP matrix using dual-extrusion fused deposition modeling. This SMP/cTPU composite enables electrothermal activation through Joule heating while preserving the intrinsic thermomechanical behavior of the base SMP. Compared to plain SMP, the composite maintained similar shape memory performance and showed improved structural stability. The electroactive SMP/cTPU composite was first optimized for a simple geometry and later extended to complex auxetic structures with multiple independent cTPU paths along the inclined struts, enabling remote and selective activation within the same structure. Experimental multi-staged shape memory cycle on a single-cell auxetic structure was supported by viscoelastic finite element simulations implemented in ABAQUS, showing strong agreement. Numerical studies were further extended to multicellular auxetic structures, where selective heating of the inclined struts demonstrated advantages over conventional heating.

Overall, this dissertation establishes scalable, low-cost and experimentally validated methods for achieving remote and selective activation in 4D printed structures, accelerating their applicability in adaptive and reconfigurable engineering structures.