



HUTECH
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Viet Nam
Centre for the
Fourth Industrial
Revolution

GSETS 2025
GREEN SOLUTIONS & EMERGING TECHNOLOGIES FOR SUSTAINABILITY

PROCEEDINGS

Of **The 2nd International Conference on**

**GREEN SOLUTIONS & EMERGING TECHNOLOGIES
FOR SUSTAINABILITY - GSETS 2025**



TRANSPORT PUBLISHING HOUSE

PROCEEDINGS

Of The 2nd International Conference on

**GREEN SOLUTIONS & EMERGING TECHNOLOGIES
FOR SUSTAINABILITY – GSETS 2025**



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FOREWORD

The 2nd International Conference on "**Green Solutions and Emerging Technologies for Sustainability**" (GSETS) is a prestigious global scientific event that showcases the latest advancements in Material Science, Green Solution & Technology, Data Science, Artificial Intelligence, and other emerging technologies aimed at furthering the Sustainable Development Goals (SDGs). This conference, organized by HUTECH University and Viet Nam Centre for the Fourth Industrial Revolution (C4IR), is part of a series of events commemorating the 30th anniversary of the institution, from April 26, 1995, to April 26, 2025. GSETS 2025 presents an invaluable opportunity for researchers and scientists to exchange ideas, engage in discussions, and explore collaborative efforts in research and technology transfer within the relevant fields.

GSETS 2025's extensive scientific content is founded on the significant contributions of experts, scientists, and scholars from 12 different countries. The conference has garnered substantial interest, featuring 07 plenary talks, 26 invited presentations, and 220 submissions across a range of publishing options. These options include the Conference Proceedings, the Journal of Materials and Emerging Technologies for Sustainability (METS), a Special Issue of the Journal of Development and Integration (JDI), as well as Special Issues of the Vietnam Journal of Mechanics (VJM) and the Beilstein Journal of Nanotechnology (BJNANO). All accepted manuscripts have undergone a plagiarism check using Turnitin.

Furthermore, it is essential to acknowledge the invaluable contributions of the organizers, reviewers, participants, sponsors, and scientific journals, all of whom have played a pivotal role in ensuring the success of GSETS 2025. Together, these contributions highlight the collective commitment to advancing knowledge in sustainability and emerging technologies at GSETS 2025.

As GSETS 2025 unfolds, I sincerely hope that each participant will appreciate the significance of this year's conference. It is my aspiration that attendees will enhance their professional networks and develop new ideas to effectively address the challenges of sustainability. Your active involvement is vital for promoting collaboration and advancing our shared mission toward sustainable solutions.

Publishing Committee of GSETS 2025 Conference

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Launching ceremony of "Materials and Emerging Technologies for Sustainability" Journal

& The 2nd International Conference on GREEN SOLUTIONS AND EMERGING TECHNOLOGIES FOR SUSTAINABILITY (GSETS 2025) Ho Chi Minh City, 10-11 April 2025

Website: hutech.edu.vn/gsets2025
Email: gsets@hutech.edu.vn

PROGRAM	
DAY 1 - Thursday, April 10, 2025	
7:30 - 8:00	Registration Place: E3 Yard - Thu Duc Campus
8:00 - 9:00	<p>Launching ceremony of "Materials and Emerging Technologies for Sustainability" (METS) Journal</p> <p>Room: Hall E3-05.01 - Thu Duc Campus</p> <ul style="list-style-type: none"> - Welcome speech from Chairman of HUTECH University - Speech from Representative of World Scientific Publishing - Speech from Editor in Chief of METS Journal - Introduction of Editorial Board of METS Journal
9:00 - 10:00	<p>Opening ceremony of The 2nd International Conference on "Green Solutions and Emerging Technologies for Sustainability" (GSETS 2025)</p> <p>Room: Hall E3-05.01 - Thu Duc Campus</p> <ul style="list-style-type: none"> - Introduction of GSETS 2025 - Speech from Vice Chairman of Ho Chi Minh City People's Committee - Speech from Representative of Centre for the Fourth Industrial Revolution - Welcome speech from President of HUTECH University
10:00 - 12:00	<p>Plenary Session 1</p> <p>Room: Hall E3-05.01 - Thu Duc Campus</p> <p>Chairperson: <i>Prof. Marco Abbati, University of Bologna, Italy & Prof. Yuping Wu, Southeast University, China</i></p>
10:00 - 10:40 PL1	Recent Advances in Composite Polymer Electrolytes Integrated with Inorganic Fillers <i>Prof. Kim, Jae Hyun, Daegu Gyeongbuk Institute of Science & Technology, South Korea</i>
10:40 - 11:20 PL2	Artificial Intelligence in Computational Mechanics <i>Prof. Jaehong Lee, Sejong University, South Korea</i>
11:20 - 12:00 PL3	Nature based Solutions of The Sustainable Management of the Environment: Examples from Italy <i>Prof. Marco Abbati, University of Bologna, Italy</i>
12:00 - 13:00	Lunch Buffet - 2 nd Floor E2 Building - Thu Duc Campus

Parallel Session 1: E2 Building - Thu Duc Campus						
	AMGM-1 Room: E2-03.03 Chairperson: Prof. Chunyi Wang & Assoc. Prof. Kah Hon Leong	AMGM-2 Room: E2-03.04 Chairperson: Prof. Xianyu Frank Bai & Prof. Le Van Canh	DSAI-1 Room: E2-03.08 Chairperson: Prof. Jaehong Lee & Prof. Nguyen Xuan Hung	DSAI-2 Room: E2-04.03 Chairperson: Assoc. Prof. Ritesh Chugh	STSD-1 Room: E2-04.04 Chairperson: Prof. Marco Abbati & Assoc. Prof. Nguyen Hong Quan	STSD-2 Room: E2-04.08 Chairperson: Prof. C. T Aravindakumar
	11 Polymer Nanocomposite and Mixed Matrix Green materials toward the Next Generation of Sustainable Membranes Prof. G. Arthaneswarar, NITT, India	15 Magneto-rheological Fluid and Applications in Force-feedback Systems Prof. Nguyen Quoc Hung, HUTECH, Vietnam	18 Bridging Deep Learning and Topological Data Analysis for Sustainable Intelligence Dr. Pham The Anh Phu, HUTECH, Vietnam	O18 Enhancing E-Commerce Store Clustering Using Frequent Itemset Mining and Mixed Data Analysis Dr. Huong Bui, HUTECH, Vietnam	I12 The Role of Digital Technologies in Firm Performance: Evidence from An Emerging Economy Assoc. Prof. Phan Dinh Nguyen, HUTECH, Vietnam	I13 Sustainable Development Goals (SDGs) in Malaysia: The Chemistry way for a sustainable future Assoc. Prof. Collin G. Joseph, UMS, Malaysia
	12 Engineering Nanostructures for Hydrogen Energy: Photoelectrochemical Water Splitting and Solid Storage Prof. Nguyen Thanh Tung, IMS, VAST, Vietnam	16 On the Semi-Active Vibration Control System with Energy Harvesting Assoc. Prof. La Duc Viet, IMECH, VAST, Vietnam	O10 Combating Credit Card Fraud in this AI era: A Multi-Method Approach Dr. Nguyen Phan Anh Huy, HCMUTE, Vietnam	O19 Application of Machine Learning Models to Predict the Relationship Between Air Pollution, Ecosystem Degradation, Health Disparities and Lung Cancer in Vietnam Dr. Ngoc Hong Tran, VGU, Vietnam	O25 Inner Transformation and Its Relationship with The Sustainable Development Goals Dr. Leonie Hallo, Adelaide Univ., Australia	I14 Enhanced Catalytic Performance of Metal Oxide-Based Systems for Biorefinery Assoc. Prof. Jonggol Tantirungrotechai, Mahidol Univ., Thailand
13:10 - 14:20	O1 Commercial Single-Catalyst Coating on Polymeric Nanofiber Membranes: Mechanism, Properties, and Applications in Scalable Photocatalytic NOx Degradation Dr. Minh-Thuan Pham, CSU, Taiwan	O5 Hysteresis Modeling of A Solenoid Pneumatic Valve using Long-Short Term Memory Networks Dr. Tuan Luong, Sungkyunkwan Univ., South Korea	O11 Enhanced Medical Image Generation through Advanced Latent Space Diffusion Dr. Quang-Thinh Bui, TGU, Vietnam	O20 Wisdom Model: A Sustainable Framework for Effective Developing Thinking Competencies in The AI Era Dr. Trung Nguyen Quang, HUTECH, Vietnam	O26 Research on Urban Drainage Pipeline Maintenance Policies and the Application of Digital Technology in China Assoc. Prof. Lihua Chen, CQVIE, China	O33 Synthesis of Adsorbent Material to Remove Tetraacycline Antibiotics in Aquaculture Water Dr. Hai Son Truong-Lam, HCMUS, VNU-HCM, Vietnam
	O2 Dopant-Induced Charge Redistribution on the 3D Sponge-like Hierarchical Structure of Quaternary Metal Phosphides Nanosheet Arrays Derived from Metal-Organic Frameworks for Natural Seawater Splitting Tran Nguyen Thuy Tien, VNU-HCM, Vietnam	O6 Magnetic and Electrical Properties of 17-4PH and Tool Steels by Bound Metal Deposition 3D Printing: Annealed and Non-Annealed Do Qui Duyen, VGU, Vietnam	O12 Small Object Detection for Waste Management: Combining YOLO and Slicing Aided Hyper Inference (SAHI) Vinh Hoang The, VGU, Vietnam	O21 Air Pollution Forecasting Model for Green and Sustainable Development Vo Hoang Khang, HUTECH, Vietnam	O27 Evaluating Renewable Energy Consumption Efficiency in the Association of Southeast Asian Nations Utilizing the Data Envelopment Analysis with the Undesirable Output Model Tram Thi Mai Nguyen, NKUST, Taiwan	O34 Enhancing photocatalytic activity for hydrogen evolution reaction by doping nano nickel on tubular graphitic carbon nitride (g-C ₃ N ₄) Nguyen Duy Minh, HCMUT, VNU-HCM, Vietnam
		O13 Support System to Determine Pneumonia Based On X-Ray Images Using Machine Learning Bui Xuan Tung, TDU, Vietnam	O22 Embedded Machine Learning for Fault Detection in Conveyor Systems Using Multi-Sensor Data and Discrete Wavelet Transform Khang Hoang Vinh Nguyen, VGU, Vietnam			
Poster session Room: E1 Lobby - Thu Duc Campus Chairperson: Prof. Kim, Jae Hyun, Prof. K. Jothivenkatachalam, Assoc. Prof. La Duc Viet, Assoc. Prof. Thai Van Nam, Dr. Ly Thien Trang, Dr. Tran Ngoc Quang, Dr. Huynh Quoc Bao, Dr. Pham The Anh Phu						
14:20 - 15:50						
15:50 - 16:10	Tea Break					

Parallel Session 2: E2 Building - Thu Duc Campus										
16:10 - 17:10	AMGM-3 Room: E2-03.03 Chairperson: Prof. Nguyen Thanh Tung & Assoc. Prof. Nguyen Thai Hoang		AMGM-4 Room: E2-03.04 Chairperson: Prof. Nguyen Trung Kien & Prof. Nguyen Quoc Hung		DSAL-3 Room: E2-04.03 Chairperson: Assoc. Prof. Nguyen Anh Thi & Assoc. Prof. Nguyen Thanh Phuong		STSD-3 Room: E2-04.04 Chairperson: Assoc. Prof. Phan Dinh Nguyen		STSD-4 Room: E2-04.08 Chairperson: Assoc. Prof. Nguyen Hung	
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	14	Carbon Aerogel from Coconut Fiber with Thiourea cross-linking agent for Capacitive Deionization Applications Assoc. Prof. Nguyen Thai Hoang, HCMUS, VNU-HCM, Vietnam	O7	Forming Limit Prediction of Advanced High-Strength Steels (AHSS) Using an Enhanced Ductile Damage Model Dr. Hao H. Nguyen, UTC, Vietnam	O14	Enhancing Ramp Safety in Aviation Through Virtual Reality: A Sustainable and Risk-Free Training Approach Dr. Van Thuan Luu, VAA, Vietnam	111	The Impact of Green Factors on Environmental Management Accounting to Enhance Environmental Performance: A Case Study of Manufacturing Enterprises in Vietnam Assoc. Prof. Tran Van Tung, HUTECH, Vietnam	O29	An Analytical Study of Electro-Conjugate Fluid Micropump under the Effects of the Collector Electrode Assoc. Prof. Ich Long Ngo, HUST, Vietnam
	O3	Evaluation on The Utilization of Glass Textile within the Cementitious Composites Dr. Van Doan Truong, TLU, Vietnam	O8	Investigation Factors Affecting Tensile Strength based on Taguchi Method of PLA Parts Manufactured by Delta-FDM 3D Printing Technology Tran Anh Khoa, HCMUTE, Vietnam	O15	Augmented Security Solution for X448 Protocol Implemented in Authentication and Data Protection of Smart Home Networks Dr. Van Nghi Nguyen, ACT, Vietnam	O23	Evaluating the Sustainable Performance of International Airlines: Application of Shannon entropy and CoCoSo methods Le-Thanh-Hieu Dang, NKUST, Taiwan	O30	Theoretical Analysis of A Solar Water Distillation Using Receiver and Condenser Tubes Dr. Hieu Tri Le, HUTECH, Vietnam
	O4	In-situ Atomic-Layer-Resolved Electrical Characterization of SnO ₂ Thin Films Deposited by Atmospheric Pressure Spatial Atomic Layer Deposition Dinh Nam Nguyen, Phenikaa Univ., Vietnam	O9	Research on A Flow-Mode Magneto-Rheological Impact Damper with Stroke-Activated Capability Huu-Quan Nguyen, IJH, Vietnam	O16	A Comparative Analysis of Learning Algorithms for Solar Power Generation Forecasting Vu Thi Ngoc Han Danh, HCMUTE, Vietnam	O24	Evaluating the Impact of Project Design Education on Students' Innovation and Entrepreneurial Thinking: An empirical case study at HUTECH University Xuan-Hung Nguyen, HUTECH, Vietnam	O31	Design and Implementation of a Battery Management System for Lithium-Ion Batteries with Real-Time Monitoring and Remote Control Thanh-Danh Truong, TDMU, Vietnam
					O17	Classification of Photovoltaic Fault Using CatBoost Classifier Optimized QPSO Hoang-Phuong Van, CYCU, Vietnam			O32	Development of a Testing Platform for Fuel Cell Thermal Management Systems Do Thi Ngoc Anh, HANU, Vietnam
GALA Dinner - Hotel										
17:10 - 22:00										

DAY 2 - Friday, April 11, 2025						
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	I16 Assoc. Prof. Le Van Lich, HUST, Vietnam Nanomechanical Energy Storage Capacity and Sealing Laws of Three-Dimensional Graphene Nanostructures	I18 Dr. Tran Ngoc Quang, INOMAR, VNU-HCM, Vietnam Green Hydrogen Production from Seawater Electrolysis	I20 Dr. Nguyen Viet Huong, Phenikaa Univ., Vietnam Atmospheric Pressure Spatial Atomic Layer Deposition: A Green Solution for Advancing Functional Thin Films and Sustainable Technologies	I22 Prof. Usha K. Aravind, CUSAT, India Polyelectrolyte Multilayer-Modified Membranes for Sustainable Dye and Salt Separation in Textile Effluent Treatment	I24 Assoc. Prof. Doan Le Hoang Tan, INOMAR, VNU-HCM, Vietnam Advancing Targeted Cancer Therapy with Biodegradable Porous Nanoparticles	I26 Assoc. Prof. Dang Tan Hiep, HUIT, Vietnam Study on the Modified Red Mud for the Removal of Pb ²⁺ in Industrial Wastewater
	O35 Natthakki Singhanakalsi, Thammasat Univ., Thailand A DFT Study of Selective Dye Adsorption on MCM-41 Mesoporous Materials	O37 Dr. Thanh-Tam Mai, Kyoto Univ., Japan Multiaxial Stress-Softening and Crack Behavior of Soft Materials	O39 Assoc. Prof. Vannhu Le, LQDTU, Vietnam Improving Image-Quality of Wide-Field Optical Microscopy by Removing Background	O41 Dr. Huu Phuc Dang, IUH, Vietnam Enhance Photoelectrochemical Performance BIO derived BiVO ₄ Film By Controlled Intensity Current Electrodeposited	O43 Vinh Thanh Chau Doan, HCMUS, VNU-HCM, Vietnam A Glucose-Derived Bifunctional Carbonaceous Catalyst for the Synthesis of Furfural from Xylose	O45 Dr. Minh Vuong Pham, DFIM-Group, Vietnam Off-Grid Green High-Purity Hydrogen Production Using a 10kW Electrolyser Powered by Solar Energy via DC/DC Converter
	O36 Hon Nhtien Le, HCMUS, VNU-HCM, Vietnam Supramolecular Hydration Structure of Graphene-Based Hydrogels: Density Functional Theory, Green Chemistry and Interface Application	O38 Ann T. M. Vo, HCMUT, VNU-HCM, Vietnam Palladium-Nickel (PdNi) Electrochemical Catalyst Supported by High Porous Amorphous Bio-Silica from Rice Husk for Glucose Sensor	O40 Dr. Le Minh Tam, HCMUTE, Vietnam Study on Synthesis of Vegan Leather from Agricultural Waste of Dragon Fruit Plants	O42 Hung-Anh Tran Vu, Phenikaa Univ., Vietnam Advanced Atomic Layer Deposition Coatings for UV Protection and Dust Resistance on Polymer Composite Material	O44 Hieu D. Nguyen, HCMUT, VNU-HCM, Vietnam Functional Bio-Packaging Enhanced with Nanocellulose from Rice Straw and Cinnamon Essential Oil Pickering Emulsion for Fruit Preservation	O46 Le Ngoc Can, HCMUS, VNU-HCM, Vietnam Fabrication of TiO ₂ Electrodes for Water Splitting of Hydrogen Evolution Reaction
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8:45 - 11:40	Plenary Session 2 Room: Hall E3-05.01 - Thu Duc Campus Chairperson: Prof. Kenji Urayama, Kyoto University, Japan & Prof. Kim, Jae Hyun, Daegu Gyeongbuk Institute of Science & Technology, South Korea Research and Development of Electrochemical Energy Storage in China to Push Reduction of Carbon Emission Prof. Yuying Wu, Southeast University, China					
9:00 - 9:40	PL4	Mission Possible: Aligning Science and Technology with Societal Needs Assoc. Prof. Ritesh Chugh, Central Queensland University, Australia				
9:40 - 10:20	PL5	Illuminating Cracks: Advanced Imaging in Soft Solid Mechanics Prof. Kenji Urayama, Kyoto University, Japan				
10:20 - 11:00	PL6	How Can Digital Technologies and AI Help Decarbonise The Building Industry and Address Productivity Challenges? (Online via Google Meet) Prof. Tuan Ngo, The University of Melbourne, Australia				
11:00 - 11:40	PL7	Awarding and Closing Ceremony - Best poster award - Closing speech from Vice Chairman of HUTECH University				
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12:30 - 13:30	Ho Chi Minh City Tour					
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Enhancing interfacial bond strength of ultra-high-performance fiber-reinforced concrete with calcium carbonate nanoparticles

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ABSTRACT

In this study, the effect of calcium carbonate nanoparticles (CCNPs) on the mechanical performance of ultra-high-performance fiber-reinforced concrete (UHPFRC) was investigated. Experiments were conducted with different dosages of CCNPs, ranging from 0% to 4.0% by weight of the cement. Steel fiber pullout tests were carried out to determine the bond strength of UHPFRC with CCNPs under static conditions. The experimental results indicated that adding CCNPs to UHPFRC improved markedly their bond strengths. Among the different CCNPs contents used, the UHPFRC with 3.0% CCNPs experienced the highest strength enhancement, while those with 1.0% CCNPs exhibited the lowest value. The highest bond strength (τ_{peak}) achieved was 14.52 MPa, and the corresponding equivalent bond strength (τ_{eq}) was 14.09 MPa. Enhancing the bond strengths of UHPFRC was attributed to the addition of CCNPs, which densified the interfacial transition zone around the steel fiber surface and the UHPFRC matrix. As the CCNPs contents increased from 1.0% to 4.0%, the compressive strength of UHPFRC was enhanced, attaining its highest value of 204.40 ± 4.26 MPa at 3.0% CCNPs content. However, the compressive strength of UHPFRC was reduced as the NS content ranged from 3.0% to 4.0%. Furthermore, the addition of CCNPs decreased the workability of UHPFRC, with flowability values all lower than 186 mm for matrices incorporating CCNPs, compared to 245 mm for the control matrix.

Keywords: calcium carbonate nanoparticles, UHPFRC, bond strength.

1. INTRODUCTION

Ultra-high-performance fiber-reinforced concrete (UHPFRC) is being widely researched and applied in practical constructions (Shi et al., 2015). UHPFRC is produced with a low water-to-binder ratio, typically ranging from 0.14 to 0.20. Additionally, adding various types of fiber reinforcement to the UHPFRC design reduces shrinkage and minimizes the formation of cracks in the concrete (Pyo et al., 2016; Wille et al., 2014).

The application of nanometer-sized materials to enhance concrete properties has attracted significant interest from researchers in recent years. Ghafari et al. (2014) pointed out that the use of nano-SiO₂ (NS) reduces the workability of UHPFRC, but NS enhances the compressive strength of UHPFRC at an early age. Camiletti et al. (2013) demonstrated that calcium carbonate nanoparticles (CCNPs) improve the early-age strength of UHPFRC.

The addition of CCNPs (2.5% to 5.0%) increased the compressive strength of UHPFRC by 32% to 75% after 24 hours casting, when compared to the control mix without CCNPs.

The bond characteristics of UHPFRC are primarily governed by the properties of the interfacial transition zone (ITZ) between the fibers and matrix (Kim, et al., 2012). The introduction of nanoparticles (NPs) in concrete is likely to enhance the interfacial bond strength of fibers, owing to the strengthened properties at the ITZ of concrete et al., 2021). According to Wille and Loh (Wille & Loh, 2010), the incorporation of 0.022% nano-carbon fibers into the composition enhanced the pullout load of steel fibers in UHPFRC by 40%. The addition of 1.0% NS to UHPFRC at static pullout rates produced a 35% improvement in maximum bond strength and a 70% increase in pullout energy (Wu, et al., 2017). Additionally, Wu et al. (Wu et al., 2018) found that incorporating 3.2% CCNPs into UHPFRC resulted in a 45% increase in bond strength compared to UHPFRC without CCNPs.

Although the bond behaviors of UHPFRC with some NPs have been examined, there is a gap in understanding the effect of CCNPs contents on the fiber–matrix bond properties of UHPFRC. The link between the microstructural properties of the ITZ and the rate-sensitive fiber pullout resistance in UHPFRC is still yet to be explored. Therefore, in this study, the effects of CCNPs contents on UHPFRC properties, including workability, compressive strength, and bond strength of steel fibers, will be evaluated through experiments.

2. EXPERIMENTAL ANALYSES

2.1. Preparing materials and specimens

Table 1 presents the mixed proportions of the sample compositions used in this study. The CCNPs contents range from 0.0 to 4.0%, corresponding to the mixes U00, U10, U20, U30, and U40. The composition of the material mix in this study was derived from reference (Phi & Thuong, 2024). The CCNPs, with 98.0% CaCO_3 , had an average particle size of 50 nm. Besides, the average particle sizes are as follows: sand ranges from 210 to 250 μm , silica fume ranges from 0.1 to 1.0 μm , and silica powder is 10 μm . A superplasticizer with a 30% polycarboxylate ether concentration is used to increase the flowability of the concrete. The water-to-cement ratio (W/C) used in this study was 0.21. The steel fibers had a diameter of 0.3 mm and a length of 30 mm (Table 2).

The preparations of the mixtures containing the CCNPs were carried out as follows (Lee et al., 2019): Step 1 – Disperse the CCNPs in water and half of the superplasticizer as per the mix design for 2 hours; Step 2 – Mix the cement, sand, silica fume, and silica powder dry for 5 minutes; Step 3 – Gradually pour the CCNPs solution, water, and superplasticizer from Step 1 into the mixture from Step 2 over a period of 2 minutes; Step 4 – Gradually add the remaining superplasticizer as required into the mixture and continue mixing for 5 minutes.

Cube-shaped specimens with exact dimensions of 50 mm x 50 mm x 50 mm were fabricated to determine the compressive strength of matrices. In addition, Bell-shaped pullout specimens were utilized to examine the pullout resistance of the fibers in matrices,

as illustrated in Fig. 1. A fiber was fixed in molds with an embedded length of 5 mm before casting. After the casting process, all specimens were covered with plastic sheets and stored at room temperature for 48 hours. Following demolding, the samples underwent water curing at 90 ± 2 °C for 3 days. The specimens were tested after 28 days in dry conditions.

Table 1. Composition of matrices

Matrix	Cement	CCNPs	Silica sand	Silica fume	Silica powder	Superplasticizer	W/C
U00	1.00	-	1.1	0.25	0.3	0.07	0.21
U10	0.99	0.01	1.1	0.25	0.3	0.07	0.21
U20	0.98	0.02	1.1	0.25	0.3	0.07	0.21
U30	0.97	0.03	1.1	0.25	0.3	0.07	0.21
U40	0.96	0.04	1.1	0.25	0.3	0.07	0.21

Table 2. Characteristics of smooth steel fibers (V.P. Dang & Kim, 2023)

Diameter (mm)	Length (mm)	Density (g/cm ³)	Tensile strength (MPa)	Elastic modulus (GPa)
0.3	30	7.9	2447	200

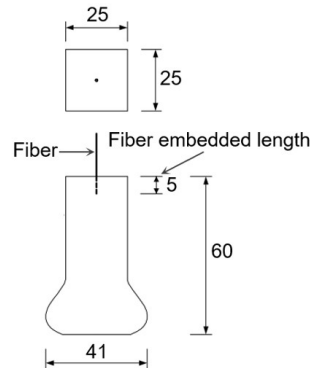


Figure 1. Pullout specimen geometry (unit: mm) (Dang & Kim, 2023)

2.2. Testing setup and procedure

The workability of mixtures was tested using a cone-shaped device with a height of 60 mm, a large base diameter of 100 mm, and a small base diameter of 70 mm. The workability testing steps followed the procedure outlined in reference (EFNARC, 2002). Figure 2 presents the universal testing machine (UTM) with a constant rate of 1.0 mm/min that was used to determine the compressive strength of matrices. Besides, Figure 3 displays the pullout test machine with a 5 kN capacity, used for obtaining the bond strength of matrices.

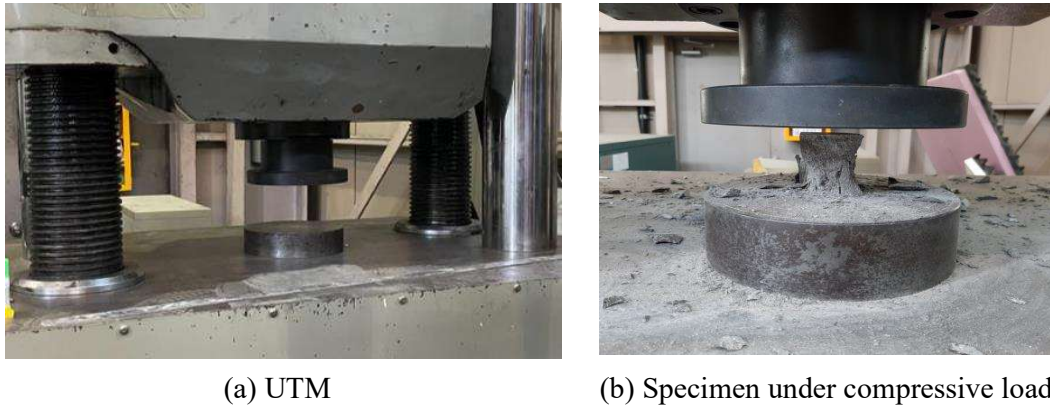


Figure 2. UTM system and Specimen after compression



Figure 3. Pullout test machine

3. RESULTS AND DISCUSSION

3.1. Influence of CCNPs content on the workability of UHPFRC

Figure 4 presents the flow spread results for the UHPFRC mixtures. The findings indicate that the flowability of the mixtures containing CCNPs was lower (186 mm) compared to the control sample (212 mm). Furthermore, an increase in CCNPs content from 1.0% to 4.0% led to a reduction in flowability. The flow values for the samples in mixtures U10, U20, U30, and U40 were 186 ± 13 , 182 ± 11 , 167 ± 7 , and 163 ± 5 mm, respectively. The decrease in flow in the mixtures as the CCNPs content rose can be attributed to the increased surface area of the mixture components caused by CCNPs, which requires additional water to fill the voids and coat the surfaces of the aggregate particles (Taylor, 1997; Wu et al., 2016). However, in this study, the water and superplasticizer content were kept constant in all matrices (Table 1), which resulted in a decrease in flow as the CCNPs content increased. An increase in the CCNPs content in UHPFRC led to a decrease in its workability, which aligns with the findings reported in the literature (Ghafari et al., 2014; Wu et al., 2018).

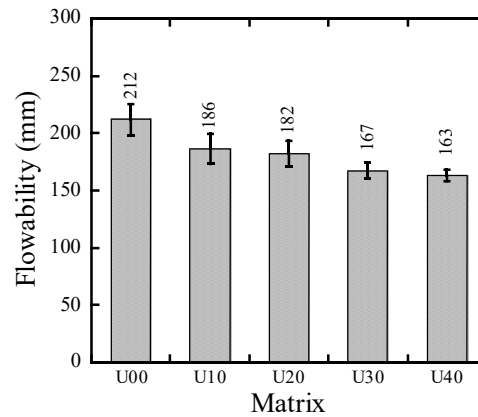


Figure 4. Workability of matrices containing different CCNPs contents

3.2. Influence of CCNPs on the compressive strength of UHPFRC

Figure 5 demonstrates the substantial influence of CCNPs contents incorporation on the compressive strength of UHPFRC. The inclusion of CCNPs at levels from 1.0% to 4.0% enhanced the compressive strength of UHPFRC by 1.55% to 9.96%, compared to the control sample. The corresponding compressive strengths were 193.50 ± 3.15 MPa for 1.0%, 195.77 ± 3.95 MPa for 2.0%, 204.40 ± 4.26 MPa for 3.0%, and 188.76 ± 2.92 MPa for 4.0% CCNPs (Fig. 5). The observed compressive strength in this study were slightly higher than those in reference (Phi & Thuong, 2024), even with identical mix compositions, which could be attributed to variations in casting and experimental conditions. In addition, all matrices using CCNPs exhibited higher compressive strength in comparison to the control sample U00 (185.88 ± 2.88 MPa) without CCNPs (Fig.5). The improvement of compressive strength in UHPFRC is attributed to the unique characteristics of CCNPs, which enhance the microstructure and increase the proportion of C-S-H in the cement hydration products, ultimately leading to improved strength performance (Dang & Kim, 2023).

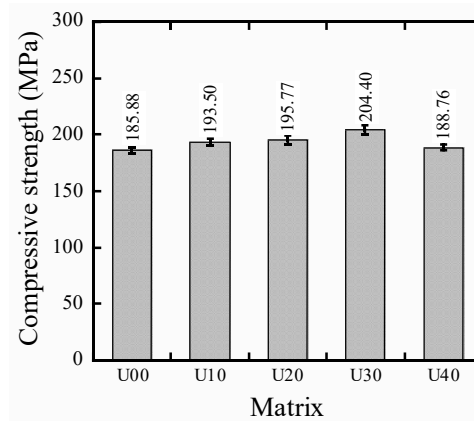


Figure 5. Compressive strength of matrices with varying CCNPs contents

3.3. Influence of CCNPs on bond strength of UHPFRC

Figure 6 presents the correlation between average loads and steel fiber displacement during the pullout process. UHPFRC samples containing CCNPs demonstrated greater bond

strength compared to the control sample. The peak load for samples of U10, U20, U30, and U40 matrices were 51.22, 58.22, 67.87, and 54.40, respectively, while the control sample M00 exhibited a value of 48.07 N (Fig. 6).

The bond strengths of steel fibers in matrices are calculated using equations (1) and (2) (Park, et al., 2019):

$$\tau_{eq} = \frac{2P_E}{\pi d_f L_{em}^2}, \quad (1)$$

$$\tau_{peak} = \frac{P_{Peak}}{\pi d_f L_{em}}, \quad (2)$$

where P_E represents the pullout energy, P_{Peak} is the peak pullout load, d_f is the diameter of the straight steel fiber, and L_{em} is the embedded length of the steel fiber in matrices.

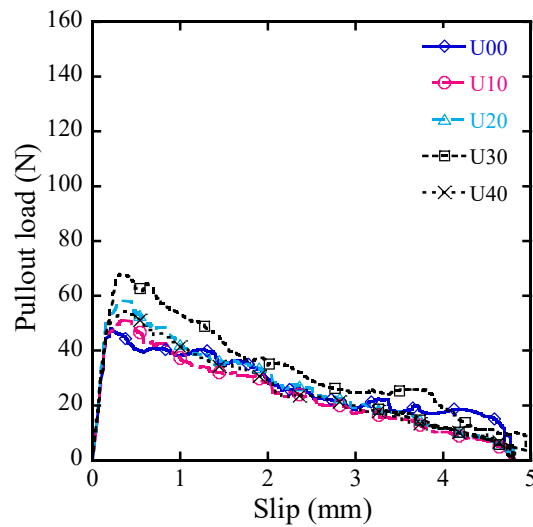


Figure 6. Load versus slip curves of matrices under pullout tests

Table 3. Mechanical behavior of steel fiber under pullout load

Matrix	P_{Peak} (N)	P_E (Nmm)	τ_{peak} (MPa)	τ_{eq} (MPa)
U00	48.07	111.07	10.58	10.15
U10	51.22	116.29	11.27	10.62
U20	58.22	132.29	12.82	12.08
U30	67.87	163.38	14.52	14.09
U40	54.40	125.69	11.98	11.48

Furthermore, among the CCNPs contents tested (0.0–4.0%) in this study, the 3.0% CCNPs content resulted in the highest values of τ_{peak} (14.25 MPa) and τ_{eq} (14.09 MPa) in matrices (Table 3). This trend is similar to the compression results presented in Section 3.2. The incorporation of CCNPs into UHPFRC resulted in improved bond strength, likely due

to enhanced densification in the transition zone around the steel fiber surface and UHPFRC (Dang & Kim, 2023). Besides, the improvements in the fiber pullout resistance of UHPFRC containing CCNPs were in close agreement with the results presented by Dang et al. (Dang & Kim, 2023). The highest enhancement in the pullout resistances of U30 (UHPFRC containing 3.0% CCNPs) can be attributed to the incorporation of optimal amounts of CCNPs in matrices. Wu et al. (Wu et al., 2018) also found that the bond strength of UHPFRC was significantly enhanced with the use of optimal dosages of CCNPs (1.6–4.8%).

4. CONCLUSION

This study examined the influence of CCNPs contents ranging from 0.0% to 4.0% on mechanical properties of UHPFRC, particularly the pullout behavior of steel fibers in UHPFRC, which was explored through experimental findings. The conclusions drawn from the study are as follows:

- The workability of UHPFRC reduces with the addition of CCNPs in the mixtures. The flowability values for mixtures containing CCNPs are consistently lower than 186 mm, while the flow of the control sample is 212 mm. As the CCNPs content increases from 1.0% to 4.0%, the flow of UHPC decreases from 186 ± 13 mm to 163 ± 5 mm.
- The compressive strength of matrices enhances as the CCNPs content increases from 1.0% to 3.0%, with the highest value of 204.40 ± 4.26 MPa observed at 3.0% CCNPs. On the other hand, as the CCNPs content increases from 3.0% to 4.0%, the compressive strength decreases.
- The UHPFRC containing CCNPs content exhibited higher fiber pullout resistance than the control matrix. The addition of CCNPs to UHPFRC led to an improvement in bond strength, which can be attributed to the enhanced densification in the transition zone surrounding the steel fiber surface and UHPFRC. Among the CCNPs dosages used (0.0% to 4.0%), UHPFRC with 3.0% CCNPs achieved the highest bond strength, with τ_{peak} and τ_{eq} values of 14.25 MPa and 14.09 MPa, respectively.

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