

Houlin Xu

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Summary

- I specialize in computational mechanics and structural engineering, focusing on fracture mechanics, risk assessment, and material optimization to achieve modern fracture analysis.
- Key contributions include developing the Smooth Crack Band Model (sCBM) and conducting asymptotic analysis of systems with size effect to improve failure predictions.

Education

2020–25* **Ph.D.**, Mechanics, Materials & Structures, Northwestern University
2016–20 **BEng**, Engineering Mechanics, Dalian University of Technology
Bachelor's Thesis: *On the Vibration of Irregularly Shaped Plates Based on the Symplectic Superposition Method*

Research Experience

2020–25 Graduate Research Assistant, Northwestern University
Advisor: Prof. Zdeněk P. Bažant
2019 Summer Research Assistant, University of California, Irvine
Advisor: Prof. Lizhi Sun
2017–20 Undergraduate Research Assistant, Dalian University of Technology
Advisor: Prof. Rui Li

Projects

2023–
Present **Hydraulic Fracturing and CO₂ Sequestration in Geo-materials**

- Developed coupled multiphysics models to simulate fracture patterns in geo-materials, focusing on CO₂ mineralization efficiency and long-term stability in subsurface storage.
- Examined fracture network development in plaster, shale, and basalt, highlighting how crack branching influences reaction surface area and CO₂ storage capacity, supporting more effective carbon capture strategies.
- Contributed to advancing carbon sequestration methods by integrating chemical, mechanical, and fluid dynamic analyses, facilitating more sustainable CO₂ storage solutions.

*Expected.

- 2022–24 **Quantitative Analysis for Extreme Failure Risk Assessment**
- Developed an asymptotic probability analysis framework to estimate failure risks for complex systems, using Monte Carlo simulations with over a million trials to ensure robust statistical foundations.
 - Identified structural instability points using probabilistic methods, enabling the design of materials with optimized strength-to-weight ratios, especially for large-scale structures.
- 2022–24 **High-Performance Multiphysics Modeling in Computational Mechanics**
- Achieved a 110x speed improvement using a novel multiphysics coupling approach with high-performance computing, enabling efficient simulations for real-time fracture mechanics.
 - Developed the Smooth Crack Band Model (sCBM) to address mesh sensitivity, incorporating the “sprain” concept for more accurate failure predictions in quasibrittle materials.
 - Introduced a tensorial Lagrange multiplier method, enhancing the model’s ability to capture crack-parallel stresses and rotational gradients, providing more accurate structural reliability predictions.
- 2021–22 **Critical Analysis of Shear Load Capacity Databases**
- Conducted an integrated analysis using statistical methods and finite element modeling to optimize design processes in structural engineering.
 - Assessed the size effect as defined in the ACI code, revealing that its strength definition is approximately 30% lower than the actual size effect, highlighting the need for adjustments to enhance structural safety and efficiency.
- 2020–21 **Simulation and Automation for Composite Material Failure**
- Developed a cross-software simulation platform for automated failure prediction in composite materials, specifically for 2D woven composites used in aerospace applications.
 - Improved prediction accuracy for composite material stability by devising critical stability conditions, supporting optimized design processes for high-performance materials.

Publications

Journal Articles

- J1. **Xu, H.**, Nguyen, A. T. & Bažant, Z. P. Sprain energy consequences for damage localization and fracture mechanics. *Proceedings of the National Academy of Sciences* **121**, e2410668121 (2024).
- J2. Nguyen, A. T., **Xu, H.**, Matouš, K. & Bažant, Z. P. Smooth Lagrangian Crack Band Model (slCBM) Based on Sprain-Sprain Relation and Lagrange Multiplier Constraint of Displacement Gradient. *Journal of Applied Mechanics*, 1–19 (2024).

- J3. Li, L., Wang, B., **Xu, H.**, Nguyen, H. T., Bažant, Z. P. & Hubler, M. H. Crack-Parallel Stress Effect on Fracture of Fiber-Reinforced Concrete Revealed by Gap Tests. *Journal of Engineering Mechanics* **150**, 04024011 (2024).
- J4. **Xu, H.**, Vievering, J., Nguyen, H. T., Zhang, Y., Le, J.-L. & Bažant, Z. P. Asymptotically matched extrapolation of fishnet failure probability to continuum scale. *Journal of the Mechanics and Physics of Solids* **182**, 105479 (2024).
- J5. **Xu, H.**, Dönmez, A. A., Nguyen, H. T. & Bažant, Z. P. What We Can and Cannot Learn from a Single Shear Test of a Very Large RC Beam. *Journal of Structural Engineering* **149**, 04023113 (2023).
- J6. Dönmez, A. A., Nguyen, H. T., **Xu, H.** & Bažant, Z. P. Crack-parallel stress effect on fracture energy of plastic hardening polycrystalline metal identified from gap test scaling. *Journal of the Mechanics and Physics of Solids* **173**, 105222 (2023).
- J7. Yang, Y., An, D., **Xu, H.**, Li, P., Wang, B. & Li, R. On the symplectic superposition method for analytic free vibration solutions of right triangular plates. *Archive of Applied Mechanics* **91**, 187–203 (2021).
- J8. Li, R., Wang, H., Zheng, X., Xiong, S., Hu, Z., Yan, X., Xiao, Z., **Xu, H.** & Li, P. New analytic buckling solutions of rectangular thin plates with two free adjacent edges by the symplectic superposition method. *European Journal of Mechanics-A/Solids* **76**, 247–262 (2019).

Peer-reviewed Conference Proceedings

- C1. Bažant, Z. P., Nguyen, A. T., **Xu, H.**, Nguyen, A., Asem, P. & Labuz, J. F. *Sideways branching of hydraulic cracks under osmotic pressure gradients and its role in deep CO₂ sequestration and in fracturing in 58th U.S. Rock Mechanics/Geomechanics Symposium* (2024).
- C2. Bažant, Z. P., **Xu, H.**, Nguyen, A., Carey, B. & Khan, M. *The Prospect of Massive Sequestration of Atmospheric CO₂ in Deep Formations of Basalt or Peridotite Appraised by Fracture, Diffusion and Osmosis Analysis and Frac Analogy in 57th U.S. Rock Mechanics/Geomechanics Symposium* (2023).

Presentations

Talks

- T1. **Xu, H.**, Nguyen, A. T. & Bažant, Z. P. *Upgrade of Fracture Mechanics by Stress-Strain Relations: Limiting Damage Field Curvature* EMI Conference 2024. 2024.
- T2. **Xu, H.**, Vievering, J., Nguyen, H. T., Zhang, Y., Le, J.-L. & Bažant, Z. P. *Asymptotically Matched Extrapolation of Fishnet Failure Probability to Continuum Scale* EMI Conference 2024. 2024.

Teaching

Northwestern University

2022-24	Teaching Assistant, Stability of Structures (CIV_ENV 424)
2022	Teaching Assistant, Quasibrittle Fracture and Scaling (CIV_ENV 430)
2021	Teaching Assistant & Lecturer, Mechanics of Materials I (CIV_ENV 216)

Dalian University of Technology

2017-18 Teaching Assistant, Numerical Analysis

Academic Service

Journal Reviewer

2023 Journal of Structural Engineering, ASCE

Awards & Honors

2020–24 Water P. Murphy Fellowship, Northwestern University
2020 Graduation with honor: College Graduate Excellence Award, Liaoning Province
2019 Second Prize in International Olympiad on Theoretical Mechanics, Belarus
2018 National Scholarship, Ministry of Education of China
2017 Qu Bochuan Scholarship for Academic Excellence (Highest Award for Undergraduates at DUT), Dalian University of Technology