CEE-430 QUASIBRITTLE FRACTURE AND SCALING Spring 2023

MWF 2-3:50pm, Room LG62 Instructor: Prof. Zdeněk Bažant, Illinois Registered Structural Engineer

Day	Hours	
		1. Introduction
3/28 Tu	1.5	Historical Perspective. Overview of main concepts. Relevance to quasibrittle materials (concrete, rock, tough ceramics, fiber composites, foams, sea ice, bone, wood, etc.)
		2. Essentials of Linear Elastic Fracture Mechanics (LEFM)
3/29 W	1.5	Energy release rate and fracture energy. 2.1. Westergaard's solution of crack in infinite plane,
4/5 W	1.5	Asymptotic near tip fields, modes I, II, III stress intensity factors, fracture toughness.
4/7 F	1.5	Rice's J-Integral for energy flux. Determination of LEFM parameters. Energy-based calculations of displacements from stress intensity factors.
		3. Non Linear Mechanics and Cohesive Crack Model
4/10 M	1.5	Asymptotic far-away field and crack interactions. Snapback instability at ligament tearing.
4/12 W	1.5	Fracture process zone and crack bridging zone in concrete, rocks, ceramics, etc.
4/14 F	1.5	Fracture process zone size and Irwin's characteristic length. Models of Dugdale & Barenblatt. Cohesive (fictitious) crack model of Hillerborg.
4/17 M	1.5	Compliance formulation of cohesive crack model. Softening stress-displacement relations, and relation to fracture energy. Quasibrittle vs. cohesive.
4/21 F	1.5	Work-of-fracture method for measuring fracture energy. Jenq-Shah 2-par. model. Crack-band model. Strain softening laws and their regularization. Material char. length.
		4. Equivalent LEFM, *R*-Curves and Fracture Stability
4/24 M	1.5	Resistance curve (*R*-curve). Crack equilibrium and energy analysis of fracture stability. *R*-curve
4/28 F	1.5	determination as the envelope of fracture equilibrium curve for different sizes. Fracture analysis based on *R*-curves.
		5. Scaling and Size Effect
5/1 M	1.5	Geometrically similar structures, power scaling laws. Size effects in fracture mechanics vs. plasticity,
5/3 W	1.0	scaling, or energy release. Failures at very small cracks no scaled to structure size.
5/8 M	1.5*	Size effect as a principal characteristic of quasibrittle fracture. Energy derivation of size effect law for quasibrittle materials. Asymptotic analysis.
5/12 F	1.5*	Transitional size. Experimental evidence for concrete, rock, ice, ceramics, composites, bone, foams. Determining fracture energy and process zone length from size effect measurements. QUIZ (1 hour, written). TAKE-HOME FINAL EXAM ASSIGNED
5/15 M	1.5*	Size effect on apparent fracture toughness or apparent fracture energy. Softening with long tail. Calculations of *R*-curve from size effect data. Applications to various types of structures.
5/19 F	1.5*	Brittleness and size effect in structural design Size effect in quasibrittle or cohesive crack models for concrete, rocks, composites, ice, wood. Slopes.
		6. Statistical Fracture Mechanics
5/22 M	1.0	Statistical Strength Theory and Size Effect. Weibull's weakest link theory. Extreme value distribution. Stability postulate of extreme value statistics. Statistical size effects. Finite weakness link model for quasibrittle materials.
5/26 F	1.0	Distribution of strength, static lifetime, and Evans law. Rate and thermal effects in fracture; effect of creep, and influence on size effect. Generalization of cohesive crack model. Stability of strain softening. Fatigue crack growth in quasibrittle materials, Paris law and its size dependence.
		7. Effects of Time, Rate, Creep, Temperatures, Load Cycling, Distributed Damage
5/31 W	1.0	QUIZ 60 min. (closed book, no notes)
6/2 F	1.0	Non-local continuum modeling of damage localization. Materials models for damage. Stability of crack systems, variational microplane concept.
6/7 W	3-5pm*	Final exam due (at the University scheduled exam time).

PREREQUISITES: **Solid background in mathematics and mechanics at the undergraduate level, including calculus, differential equations, mechanics, mechanics of materials, elements of continuum mechanics and theory of structures**. Recommended Texts: 1) ZP. Bažant, M. Salviato, J-L Le (2022), Quasibrittle Fracture Mechanics 2) ZP. Bažant and J. Planas (1998), Fracture and Size Effect in Concrete and Other Quasibrittle Materials, CRC Press; 3)Bažant (2002), Scaling of Structural Strength, 2nd ed. (2005), Elsevier. 4) Bažant & JL Le (2017); Probabilistic Mechanics of Quasibrittle Fract. (Oxford UP); 5) Bažant & L Cedolin (2010), Stability of Structures, 3rd ed., World Scientific (only ch.12) .**GRADING: Based on Take-home final exam 40%, Quiz 30%, Homeworks 30%.**