Distinguished Webinar in Mechanics

CNC IUTAM Canadian National Committee for International Union of Theoretical and Applied Mechanics

Professor Zdeněk P. Bažant

organized by the Canadian National Committee for IUTAM, MeMoCS, McGill University

Tuesday, March 23, 2021 at 10 am EST
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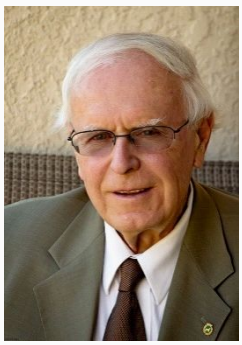

Gap Test Consequences for Quasibrittle Fracture Mechanics, Scaling and HRR Theory of Metal Fracture

Zdeněk P. Bažant

ABSTRACT: The recently conceived gap test, in which fracture is tested at various levels of crack-parallel stress σ_{xx}, indicates the need for major conceptual changes in quasibrittle fracture mechanics, and also leads to a scaling law of the HRR theory, with an alternative method to test J_{cr} in plastic-hardening metals. For quasibrittle materials such as concrete, the gap test combined with the classical size effect law and FE damage analysis reveals that the crack-parallel stresses σ_{xx}, σ_{zz} and σ_{zz} can double the Mode I fracture energy, G_f, or reduce it to zero. For plastic-hardening metals, a size effect law with an intermediate asymptote that reflects the size changes of the yielding zone is derived and verified by tests of notched aluminum beams. The main consequence for quasibrittle fracture is that the line crack models, i.e., LEFM, XFEM and cohesive crack model, are applicable only if the crack-parallel stresses σ_{xx}, σ_{zz}, σ_{xz} are nearly zero, which occurs in all standard fracture test specimens but rarely in practice. FE simulation of these effects requires considering a fracture process zone of finite width, as in the crack band model, and using a realistic tensorial damage law, such as the microplane model. The lecture ends by comments on some practical problems in which a major effect of σ_{xx} must be expected, including hydraulic fracturing of shale, beam shear or slab punch in reinforced concrete, pressure vessel or composite fuselage under biaxial tension, shear in composite wing of aircraft, composite crush cans for cars, sideways cracks in composites, frictional Mode II cracks in geology, and sea ice fractures.

References (freely downloadable as # 612, 613 and 619 from http://www.civil.northwestern.edu/people/bazant)

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Nguyen, Hoang T., Dönmez, A. Abdullah, Bažant. Z.P. (2021). "Structural Strength Scaling Law for Fracture of Plastic-Hardening Metals and Testing of Fracture Properties." Extreme Mechanics Letters 43, 101141, pp.1-12.

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SHORT BIOGRAPHY OF PROFESSOR ZDENĚK P. BAŽANT

Born and educated in Prague (Ph.D. 1963), Bažant joined Northwestern in 1969, where he has been W.P. Murphy Professor since 1990 and simultaneously McCormick Institute Professor since 2002, and Director of Center for Concrete and Geomaterials (1981-87). He was inducted to the National Academy of Sciences, National Academy of Engineering, American Academy of Arts and Sciences, Royal Society of London, the academies of Austria, Japan, Italy, Spain, Czech Rep., Greece, India and Lombardy, and Academia Europaea. Honorary Member of: ASCE, ASME, ACI, RILEM. Received the Austrian Cross of Honor for Science and Art I. Class; 7 honorary doctorates (Prague, Karlsruhe, Colorado, Milan, Lyon, Vienna, Ohio State); ASME Medal, ASME Timoshenko, Nadai and Warner Medals; ASCE von Kármán, Freudenthal, Newmark, Biot, Mindlin and Croes Medals, and Lifetime Achievement Award; SES Prager Medal; Outstanding Res. Award from Am. Soc. for Composites; RILEM Gold Medal; Exner Medal (Austria); Torroja Medal (Madrid); etc. He authored eight books: Scaling of Struct. Strength, Creep in Concrete Str., Inelastic Analysis, Fracture and Size Effect, Stability of Structures, Concrete at High Temp., Creep and Hygrothermal Effects, Probab. Mech. of Quasibrittle Str. He is one of the original top 100 ISI Highly Cited Scientists in Engrg. (www.ISIhighlycited.com). H-index: 134, citations: 79,000, i10 index: 653 (Google, incl. self-cit.). In 2019 Stanford U. weighted citation survey (see PLoS[1]), he was ranked no.1 in CE and no.2 in Engrg. worldwide. In 2015, ASCE established ZP Bažant Medal for Failure and Damage Prevention.

http://cee.northwestern.edu/people/bazant/

1 Ioannidis JPA, Boyack KW, Baas J (2020) Updated science-wide author databases of standardized citation indicators. PLoS Biol 18(10): e3000918. https://doi.org/10.1371/journal.pbio.3000918