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Design of New Materials and Structures to Maximize Strength at Probability Tail: A Neglected Challenge for Quasibrittle and Biomimetic Materials

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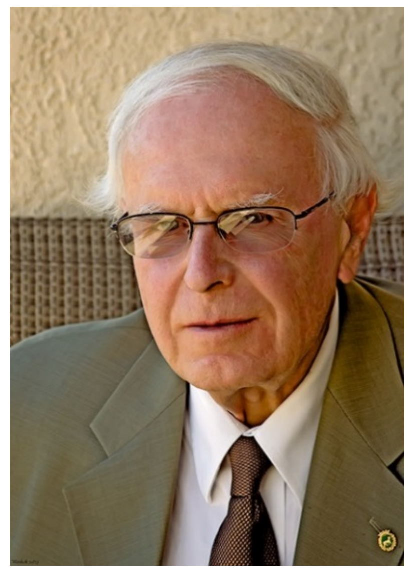

Date: Wednesday, April 25th, 2018
Time: 5 pm – 6:20 pm
Venue: Easton Hub Auditorium
101 Bevier Road
Piscataway, NJ 08854-8007

Biography: Born and educated in Prague, 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 Geomaterials (1981-87). He was inducted to NAS, NAE, Am. Acad. of Arts & Sci., Royal Soc. London; to the academies of Italy (Lincei), Austria, Spain, Czech Rep., Greece (Acad. of Athens) and Lombardy; to Academia Europaea, Eur. Acad. of Sci. & Arts. Honorary Member of: ASCE, ASME, ACI, RILEM; received 7 honorary doctorates, the Austrian Cross of Honor for Science and Art 1st Class from Pres. of Austria; ASME Timoshenko, Nadai and Warner Medals; ASCE von Karman, Newmark, Biot, Mindlin and Croes Medals and Lifetime Achievement Award; SES Prager Medal; RILEM L'Hermite Medal; Exner Medal (Austria); Torroja Medal (Madrid); etc. He authored seven books. In 2015, ASCE established ZP Bažant Medal for Failure and Damage Prevention. He is one of the original top 100 ISI Highly Cited Scientists in Engrg. His 1959 mass-produced patent of safety ski binding is exhibited in New England Ski Museum.
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Design of New Materials and Structures to Maximize Strength at Probability Tail: A NEGLECTED CHALLENGE FOR QUASIBRITTLE AND BIOMIMETIC MATERIALS

Professor Zdeněk P. Bažant, PhD, S.E.
Northwestern University, Evanston, Illinois

Abstract: In developing new materials, the research objective has been to maximize the mean strength (or fracture energy) of material or structure. However, for engineering structures such as airframes or bridges, the objective should be to maximize the tail probability strength, which is defined as the strength corresponding to failure probability 10^{-6} per lifetime. The ratio of the distance of the tail point from the mean strength to the standard deviation depends on the architecture and microstructure of the material and is what should be minimized. For the Gaussian and Weibull distributions of strength, the only ones known up to the 1980s, this ratio is almost 2:1. For the strength distributions of quasibrittle materials, it can be anywhere in between, depending on material architecture and structure size. These materials, characterized by a nonnegligible size of the fracture process zone, include concretes, rocks, tough ceramics, fiber composites, stiff soils, sea ice, snow slabs, rigid foams, bone, dental material, many bio-materials, etc. A theory to deduce the strength distribution tail from atomistic crack jumps and Kramer's rule of transition state theory, and determine the multiscale transition to the representative volume element (RVE) of material, is briefly reviewed. The strength distribution of quasibrittle particulate or fibrous materials, whose size is proportional to the number of RVEs, is obtained from the weakest-link chain with a finite number of links and is characterized by a Gauss-Weibull grafted distribution. Comparisons with observed strength histograms and size effect curves are demonstrated. Discussion then turns to new results on biomimetic imbricated (or scattered) lamellar systems, exemplified by nacre, whose mean strength exceeds the strength of constituents by an order of magnitude. The nacreous quasibrittle material is simplified as a fishnet pulled diagonally, which makes possible an analytical solution of the strength probability distribution. The solution is verified by millions of Monte-Carlo simulations of fishnets of various shapes and sizes. After the weakest-link model and the fiber-bundle model, the fishnet is the third strength probability model that is amenable to an analytical solution. It is found that, in addition to the well-known effect on the mean strength, the nacreous microstructure provides an additional strengthening at the strength probability tail. The most important consequence of the quasibrittleness, and also the most useful way of calibration, is the size effect on mean structure strength.

Short Bio: 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 Geomaterials (1981-87). He was inducted to NAS, NAE, Am. Acad. of Arts & Sci., Royal Soc. London; to the academies of Italy (lincei), Austria, Spain, Czech Rep., India.and Lombardy; to Academia Europaea, Eur. Acad. of Sci. & Arts. Honorary Member of: ASCE, ASME, ACI, RILEM; received 7 honorary doctorates (Prague, Karlsruhe, Colorado, Milan, Lyon, Vienna, Ohio State); Austrian Cross of Honor for Science and Art 1st Class from President of Austria; ASME Timoshenko, Nadai and Warner Medals; ASCE von Karman, Newmark, Biot, Mindlin and Croes Medals and Lifetime Achievement Award; SES Prager Medal; RILEM L'Hermite Medal; Exner Medal (Austria); Torroja Medal (Madrid); etc. He authored seven books: Scaling of Structural Strength, Inelastic Analysis, Fracture & Size Effect, Stability of Structures, Concrete at High Temperatures, Concrete Creep and Probabilistic Quasibrittle Srength. H-index: 119, citations: 62,500 (on Google Feb..2018, incl. self-cit.), i10 index: 560. In 2015, ASCE established ZP Bažant Medal for Failure and Damage Prevention. He is one of the original top 100 ISI Highly Cited Scientists in Engrg. (www.ISIhighlycited.com). His 1959 mass-produced patent of safety ski binding is exhibited in New England Ski Museum.
Home: http://cee.northwestern.edu/people/bazant/

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