

THE WILLIAM E. BOEING DEPARTMENT OF  
**AERONAUTICS & ASTRONAUTICS**

... welcomes ...

**DR. ZDENEK P. BAZANT**  
NORTHWESTERN UNIVERSITY

*Probabilistic Strength, Size Effect & Lifetime of Quasibrittle Structures Based on Interatomic Break Frequency & Finite Weakest-Link Model*

The size effect on structural strength and its statistical distribution is a complex problem for quasibrittle materials because their failure behavior transits from quasi-plastic at small sizes to brittle at large sizes. These are heterogeneous materials with brittle constituents in which the size of inhomogeneity, or representative volume element (RVE), is not negligible compared to the structure size. Aside from concrete, the archetypical example, they include fiber composites, coarse-grained ceramics, rocks, sea ice, snow slabs, wood, bone, foam, stiff soil, dry snow, masonry, carton, etc., and on the micro- or nano-scale, all brittle materials become quasibrittle. Since the break probability is known exactly only for interatomic bonds (being equal to frequency), Kramer's rule of transition rate theory is applied to nano-crack jumps. Based on proving the rules of multiscale transition of tail probabilities of break to material scale, the

probability distribution of strength of one macro-scale representative volume element (RVE) is shown to have a Weibullian tail, calibrated to reach to probability 0.001, the rest being Gaussian. On the structure scale, only Type 1 failure is considered, i.e., the structure fails as soon as the first RVE fails. Hence the weakest-link model applies on the structure scale. But, crucially, the number of links is finite, because of non-negligible RVE. For increasing structure size, the Weibullian portion gradually spreads into the Gaussian core. Only in the infinite size limit the distribution becomes purely Weibull, but, importantly, with a zero threshold. Based on an atomistic derivation of the power law for subcritical macro-crack growth, a similar Gauss-Weibull transition is shown to apply to structure lifetime. The theory is then extended to the size dependence of Paris law and Basquin law for fatigue fracture, to statistics of fatigue life-

time, and to residual strength after a period of preload. The theory is shown to match the existing experimental results on the monotonic strength, residual strength after preload, static and fatigue crack growth rates, and static and fatigue lifetimes, including their distributions and size effects on the distributions. There are three essential consequences: 1) The safety factors must depend on structure size and shape; 2) To predict the pdf of strength, the size effect tests of mean strength suffice; 3) To predict the static and fatigue lifetimes, it suffices to add tests of initial subcritical crack growth rate. An interesting mathematical analogy predicting the lifetime of new nano-scale high-k dielectrics is also pointed out. Finally, an extension to structures failing only after large stable crack growth is outlined and some implications for structural analysis are discussed.



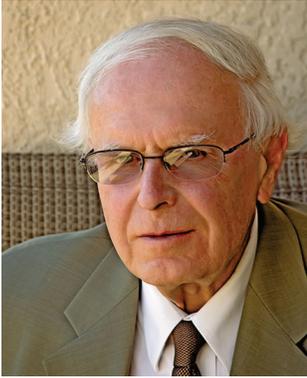
WILLIAM E. BOEING  
DEPARTMENT OF AERONAUTICS & ASTRONAUTICS  
UNIVERSITY of WASHINGTON

Monday, November 7, 2016 @ 4:00pm  
Johnson 075, UW Seattle

Visitor RSVP: [contact@aa.washington.edu](mailto:contact@aa.washington.edu)

THE WILLIAM E. BOEING DEPARTMENT OF  
**AERONAUTICS & ASTRONAUTICS**

*... Distinguished Guest Speaker ...*



**DR. ZDENEK P. BAZANT**  
NORTHWESTERN UNIVERSITY

*Professor, Civil & Environmental  
Professor, Mechanical Engineering  
Professor, Material Science*

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. 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); 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 Strength*. H-index: 111, citations 52,300 (on Google, incl. self-cit.), i10 index: 493. 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](http://www.ISIhighlycited.com)).

Read more: <http://cee.northwestern.edu/people/bazant/>



WILLIAM E. BOEING  
DEPARTMENT OF AERONAUTICS & ASTRONAUTICS  
UNIVERSITY of WASHINGTON

Monday, November 7, 2016 @ 4:00pm  
Johnson 075, UW Seattle

**Visitor RSVP:** [contact@aa.washington.edu](mailto:contact@aa.washington.edu)