SCALING OF FAILURE OF QUASIBRITTLE COMPOSITES AND THIN FILMS: ASYMPTOTIC MATCHING

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ABSTRACT:

Throughout the 20th century, it was widely believed that the size effect on structural strength has a purely statistical origin, explained by extreme value statistics based on the weakest link model, and described by Weibull statistical theory of random strength. However, beginning with the first suggestions made already in the early 1970s, it gradually transpired that, in quasibrittle materials (i.e. heterogenous brittle materials with a non-negligible fracture process zone), the mean size effect is essentially deterministic, stemming from energy release caused by stress redistribution in a structure prior to maximum load. The quasibrittle energetic size effect bridges three asymptotic power-law size effects---those of linear elastic fracture mechanics, plasticity, and Weibull theory. Renormalization group transformation does not suffice to handle the transitional nature of this quasibrittle size effect, often spanning several orders of magnitude of size. A mathematically similar problem arises on the micrometer scale in thin metallic films, as well as nanocomposites.

Asymptotic matching is a range of diverse techniques widely used in fluid mechanics, but overlooked solid mechanics. The seminar presents a method of asymptotic matching which is suitable for structural strength problems and is applicable to both quasibrittle structures and thin films. The method is based on power series expansion of the governing equation written as a function of dimensionless variables. The key idea is to choose these variables in such a way that all of them except one vanish at each asymptotic state. This general technique is first used to demonstrate three types of size effects encountered in quasibrittle materials. Then it is applied to the size effects in metals on micrometer scale, caused either by strain gradients (associated with the density of geometrically necessary dislocations), or by an epitaxially induced boundary layer having an elevated yield strength, as observed in recent pure tension tests of thin films (by Espinosa et al. at Northwestern). The size effect laws of various types are supported by numerical simulations with nonlocal Weibull theory. A technique to estimate loads of extremely small failure probability required for design is also indicated. Finally, comparisons with a broad range of experimental data for particulate composites (concretes), fiber-polymer composites and heterogeneous materials (sea ice, rocks, tough ceramics, foams, snow slabs), as well as polycrystalline Au, Al and Cu thin films, are shown.

BIOSKETCH: Born and educated in Prague (Ph.D. 1963), Bazant joined

Northwestern in 1969, where he has been W.P. Murphy Professor since 1990 and simultaneously McCormick School Professor since 2002. He was inducted to NAS and NAE, as well as Austrian Academy of Sciences, Academia di Scienze e Lettere (Italy) and Czech Engrg. Academy of Engrg; received six honorary doctorates (Prague, Karlsruhe, Colorado, Milan, Lyon, Vienna), ASCE von Karman and Newmark Medals, SES Prager Medal, ASME Warner Medal and many other honors. He authored six books (Scaling of Structural Strength, Inelastic Analysis, Fracture and Size Effect, Stability of Structures, Concrete at High Temperature, and Concrete Creep).