CURRICULUM VITAE of ZDENĚK P. BAŽANT

June 21, 2021

Personal: Born Dec. 10, l937, Prague; U.S. citizen, naturalized l976; married 1967; two children. Office tel.: (847)491-4025 (secretary 491-3351, dept. 491-3257, 491-3258). Fax: 491-4011.
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Education

C.E. (Civil Engineer), Czech Technical University in Prague (ČVUT) (with the highest distinction, straight A's all $5\frac{1}{2}$ years, first in class), 1960.

Ph.D. in Engineering Mechanics, Czechoslovak Academy of Sciences (ČSAV), Prague, l963.

Postgraduate Diploma in Theoretical Physics, Charles University, Prague, l966.

Docent (habilitatis) in Concrete Structures, Czech Technical University in Prague (ČVUT), 1967.

Registration

Registered Structural Engineer, Illinois, 1971–.

Professional Positions

Bridge Engineer, Dopravoprojekt (State Consulting Firm), Prague, Jan. 1961–Dec. 1963.

Scientific Worker and *Adjunct Assistant Professor*, Czech Technical University (ČVUT), Building Research Institute (now Klokner Institute), Prague, l964–67.

Post-Doctoral Visiting Researcher, CEBTP Paris, 1966–67.

Ford Foundation Fellow, University of Toronto, 1967–68.

Associate Research Engineer, University of California, Berkeley, 1968-69.

Associate Professor of Civil Engineering, Northwestern University, 1969–1973.

Professor of Civil Engineering, Northw. Univ., 1973–.

Staff Consultant (part-time), Nuclear Reactor Safety Div., Argonne National Laboratory, 1974–94.

Walter P. Murphy Professor of Civil and Mechanical Engineering and Materials Science,

McCormick Institute Professor, Northwestern University, 2002– (held simultaneously with Murphy Chair).

Main Administrative Positions

Director, Center for Concrete and Geomaterials, Northwestern University, 1981–1987.

Program Coordinator, Structural Engineering and Materials, Northwestern University, 1974–1978, 1992–96.

Academy Memberships

1996 **Member, National Academy of Engineering, Washington, D.C.**[1]

2002 **Member, National Academy of Sciences, Washington, D.C.**[2]

2008 **Fellow, American Academy of Sciences and Arts** (AAAS), Boston.

2015 *Foreign Member of Royal Society of London* (ForMemRS).

2018 *Foreign Member of Engineering Academy of Japan (EAJ)*, Tokyo.

1998 *Foreign Member, Academy of Engineering of Czech Republic*, Prague.

2000 *Corresponding Foreign Member, Austrian Academy of Sciences*, Vienna.

2006 *Foreign Member*, Italian National Academy (Accademia Nazionale dei Lincei), Rome.

2008 foreign *Corresponding Member*, Spanish Royal Academy of Engineering (Real Academia de Ingenieria).

2017 *Foreign Member*, Academy of Athens (national academy of Greece).

2017 *Foreign Member*. National Academy of Engineering of India.

2002 *Foreign Member*, Lombard Academy (Istituto Lombardo—Accademia di Scienze e Lettere), Milan, Italy.

2014 *Foreign Member*, Academia Europaea, London.

2008 *Member* European Academy of Sciences and Arts, Salzburg.

Honorary Doctorates

1991 Czech Technical University in Prague (ČVUT), Nov. 14.

1997 Universität Fredericiana (Technische Hochshule) Karlsruhe, Germany (Dr.-Ing.E.h., Doktor-Ingenieurs Ehrenhalber), conferred May 28, 1997, ceremony March 23, 1998)

2000 **Honorary Doctorate** (Doctor of Science h.c.), University of Colorado, Boulder.

2001 **Honorary Doctorate ('Laurea')**, Politecnico di Milano, Italy (conferred Oct. 25, 2001)[3]

[1] For "contributions to solid mechanics, particularly structural stability and size effects in fracture."

[2] Citation: "Bazant discovered the scaling law for the energetic size effect in quasibrittle structural failure bridging ductile and brittle behaviors, verified it experimentally for many important materials, showed its use for measuring fracture characteristics, and conceived nonlocal and crack-band models now widely used in numerical simulations of quasibrittle failure of structures."

[3] Cited for "...novel approaches to inelastic and time-dependent behavior of concrete, lasting contributions to quasibrittle fracture, ... innovative techniques for material instability. Bažant's law for scale effects in fracture and microplane constitutive model represent fundamental contributions..."

2004 **Honorary Doctorate** (Docteur honoris causa), I.N.S.A. (Institut national des sciences appliqueés de Lyon), Oct. 15, Villeurbane, France.

2005 **Honorary Doctorate** (Dr.techn.h.c., Ehrendoktor der technischen Wissenschaften), Technical University Vienna (T.U. Wien), Oct. 28, Austria[4].

2011 **Honorary Degree – Doctor of Engineering**, Ohio State University, Columbus (Dec. 11) [5]

Also Honorary Professor at 5 universities in PR China and Taiwan.

STANFORD UNIV. CITATION RANKING

In the 2019 Stanford University citation survey (published in PLoS, posted in Mendeley data), incl. over 200,000 engineering authors, Bažant was ranked ***no. 1 in civil engineering and no. 2 in engineering of all fields, worldwide***. He was among the top 0.0056% of over 6 million authors worldwide (the ranking excluded self-citations, was weighted for first and last author, and number of co-authors, and filtered out reciprocal citations and citation "farms"); www.asce.org/templates/award-detail.aspx?id=11613

H-index: 138, citations: 82,000, i10 index: 665 (Google, incl. self-cit.). In 2019 Stanford U. weighted citation survey (see PLoS), 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.

CITATIONS

H-index: 138 (as of May 2021), citations: 82,000, i10 index: 665 (on Google, incl. self-cit.). Top cited paper: $> 4,200$ citations. Bažant is also one of the original top 100 ISI Highly Cited Scientists in Engineering (all fields)

Medal and Prize Named after Bažant:

1 *Zdeněk P. Bažant Medal for Failure and Damage Prevention*, established in 2015 by the Am. Soc. of Civil Engrs. as an overall society medal administered by ASCE Eng. Mech. Institute (carries a monetary award of $45,000, the highest in ASCE and in the field of mechanics). Recipient chosen by a joint committee with USNC-TAM; http://www.asce.org/templates/award-detail.aspx?id=11613

2 *Z.P. Bažant's Prize in Engineering Mechanics*, given annually since 2012 by the Czech Society of Mechanics, Prague; selection comm. joint with Czech Techn. Univ. Prague and Czech Academy of Sciences; http://www.csm.cz/en/z-p-bazant-prize-for-engineering-mechanics

State Prize

2016 *Austrian Cross of Honor for Science and Art I. Class*, conferred by President of Austria in Imperial Palace (Hofburg), Vienna (awarded on the average one per year; Bažant is the first engineer since 1956 to receive this prize).

Society Medals, Prizes & Awards:

2017 *ASME Medal* (the highest honor from ASME overall).

2009 *Timoshenko Medal*, ASME (Am. Society of Mechanical Engrs.) (the highest for mechanics from ASME) [6]

2005 *Theodore von Karman Medal*, ASCE (Am. Soc. of Civil Engrs.) (the highest for mechanics from ASCE).[7]

1996 *William Prager Medal*, Soc. of Engng. Science (SES) (the highest from SES).[8]

2018 *Alfred M. Freudenthal Medal*, ASCE (the highest honor in structural safety). [9]

1996 *Newmark Medal*, joint from ASCE and ACI (the highest for structural engineering research).[10]

2008 *Nadai Medal*, ASME (the highest for materials research from ASME) [11]

2020 *Outstanding Contributions Award* from ASC (Am. Soc. for Composites)(the highest in composites).

2011 *Maurice Biot Medal*, ASCE (the highest for poromechanics) [12]

2015 *Raymond Mindlin Medal*, ASCE[13]

1997 *W.R. Warner Medal*, ASME.[14]

2008 *Wilhelm Exner Medal*, Austrian Trade Association (Gewerbeverein), Vienna (the highest for engineering research in Austria).

Other: •1997 *J.J.R. Croes Medal*, ASCE. •2003 *Lifetime Achievement Award*, from ASCE Illinois Structural Engineering Section •1993 *Medal of Czech Society for Mechanics*[15] (čestná medajle České společnosti pro mechaniku), Prague. •1990 *Torroja Gold Medal* from Building Research Institute of Spain.[16]. •1975

[4] "For accomplishments in the field of stability of structures and size effects in fracture mechanics"

[5] Cited for "distinguished career as a foremost civil and mechanical engineer" and for "significant contributions to the advancement of engineering research and education".

[6] "For fundamental contributions to scaling research in solid mechanics, particularly to the effect of the size of a structure on its strength and failure behavior; and for outstanding advances in structural stability, fracture mechanics, the micromechanics of damage, concrete creep and probabilistic mechanics"

[7] The Medal is given "in recognition of distinguished achievement in engineering mechanics"; cited "for extensive and substantive contributions to the understanding and solution of multitude of problems in engineering mechanics involving structural stability, behavior of concrete, and uncertainty and scale effects in materials and structures"

[8] Given once every two years "for contributions to solid mechanics".

[9] Given once every two years. Cited for "Developing a comprehensive theory of probabilistic mechanics of strength, lifetime, and size effect of quasi-brittle structures."

[10] The Medal is given to "a member who, through contributions to structural mechanics, has helped substantially to strengthen the scientific base of structural engineering"; cited for "fundamental contributions to the understanding of constitutive behavior of structural materials, nonlinear fracture mechanics and stability of structures."

[11] Cited "for demonstrating spurious localization instability in strain-softening models of quasibrittle materials, devising a remedy by crack-band and nonlocal damage formulations, discovering and experimentally validating the energetic size effect law for such materials, and showing applications to particulate and fiber composites.

[12] Cited "for groundbreaking contributions to the mechanics of concrete as a nano-porous material, particularly the creep and diffusion processes, thermodynamics of nano-pore water and high temperature effects, with numerical algorithms and consequences for structural design".

[13] Cited for "outstanding contributions to mechanics and for important extensions of Mindlin's results to nonlocal softening damage and size effect in quasibrittle materials".

[14] The Medal "honors outstanding contributions to the permanent literature of engineering"; cited for "important contributions to solid mechanics, focusing on the size-effect law for failure of brittle structures, modeling of material damage from softening, local and nonlocal concepts, stability and propagation of fracture and damage in material and thermodynamic concepts associated with stability of nonelastic structures."

[15] "For advances in mechanics."

[16] Cited for "outstanding achievements in the fields of structural

L'Hermite Medal from RILEM[17] (in 1975 called RILEM Medal). •2007 *Zdeněk Bažant (Sr.) Medal* (1st recipient of), Czech Techn. University, Prague (ČVUT) (medal named after late grandfather, professor of structural mechanics and rector (i.e. president) of ČVUT)[18]. •1998 *Šolín Medal*, Czech Technical University, Prague (ČVUT)[19] •1999 *Stodola Gold Medal*, Slovak Academy of Sciences, Bratislava. •2008 *Outstanding Contributions Award*, IACMAG (International Association for Computer Methods and Advances in Geomechanics). •2001 *ICOSSAR Lecture Award*, Int. Assoc. for Structural Safety and Reliability (Int. Conf., Newport Beach, CA, June 20, 2001). •2001 *D.M. Roy Lecture Award*, Am. Ceramic Society (2nd Roy Lecture, Annual Meeting, Indianapolis, April 24, 2001). •1977 *T.Y. Lin Prestressed Concrete Award* from ASCE[20]for the paper "Creep and Shrinkage in Reactor Containment Shells", with D. Carreira and A. Walser, J. Struct. Div. 101, 1975, 2117–2131). •1976 *Walter L. Huber Civil Engineering Research Prize* from ASCE [21] •2001– *ISI Award of "Highly Cited Scientist in Engineering"* [22] •1992 *Best Engineering Book of the Year*—Award for Excellence from Assoc. of Am. Publishers (Professional & Scholarly Publ. Div.), for "Stability of Structures" (with L. Cedolin). •1992 *Meritorious Publication Award*—Structural Engineers Assoc. of Ill.; for the paper "Size effect on diagonal shear failure", with M.T. Kazemi, ACI Struct. J. •2008 *Meritorious Publication Award*—Structural Engineers Assoc. of Ill.; for the paper "Justification of ACI-446 code provisions for shear design of reinforced concrete beams", with Q. Yu et al., ACI Struct. J. •2015 *RILEM Outstanding Paper Award* (Extrapolation of short-time drying shrinkage tests based on measured diffusion size effect: concept and reality, by ZP Bažant and A Dönmez, Materials and Structures, RILEM). •2018 *RILEM Outstanding Paper Award* (Statistical filtering of useful concrete creep data from imperfect laboratory tests by M. Rasoolinejad and Z.P. Bažant, Materials and Structures, RILEM). •1990 *Alexander von Humboldt Award of Senior U.S. Scientist*, from Federal Republic of Germany. •2006 *Mindlin Centennial Lecture*, US National Congress of Theoretical and Applied Mechanics, Boulder, CO, June 26, 2006. •1984 *Scientific and Technical Prize*, shared with Tong-Sheng Wang, from Ministery of Water Resources and Electric Power, Beijing, for paper "Random Temperature and Shrinkage Stresses in Aging Concrete". •1982 *IR-100 Award* (with S. Meiri), from Industrial Research and Development, for developing a new triaxial-torsional high-temperature testing machine. •1955 *National Winner, Mathematical Olympics* (for high school students), Czechoslovakia.

Honorary Society Memberships:

2007 **Hon. Mem. ASCE** (Am. Soc. of Civil Engrs.)
2012 **Hon. Mem. ASME** (Am. Soc. of Mechanical Engrs.)
2011 **Hon. Mem. ACI** (Am. Concrete Institute).
2015 **Hon. Mem., RILEM** (Int. Union of Res. in Mat. & Str., Paris).
Also •**Honorary Member** 1991 Building Research Institute of Spain, Madrid; •2005 Czech Concrete Society, Prague (Česká betonářská společnost); •2009 Czech Society of Mechanics, Prague (Česká společnost pro mechaniku); •Czech Association of Civil Engineers, Prague (Český svaz stabebních inženýrú).

Elected Fellow:

Society of Engineering Science[23] (1989);
Also elected Fellow of: •American Academy of Mechanics (1978); Engineering Mechanics Institute of ASCE (2013); •U.S. Assoc. for Computational Mechanics (USACM, 2009); •Czecho-Slovak Society of Arts and Sciences (Washington, D.C., 2003); •RILEM (Paris, 1977); •ASME (1989); •ASCE (1983); •ACI (1979). Also elected Member of Sigma Xi.

Other Honors:

2019 *Elected member of Royal Society of London Engineering Committee SC4*, which votes on new Fellows (national, FRS) and foreign members of the Society.
1976 *Outstanding New Citizen*, from Metropolitan Chicago Citizenship Council.
2004 elected *Honorary President*, IA-FRAMCOS (Int. Assoc. of Fracture Mech. of Concr. Str.)
1997 elected Professor Emeritus (by courtesy), Czech Technical University, Prague.
1998 *Special Issue in Honor of Prof. Z.P. Bažant*, Int. J. of Solids & Structures, "Special Topics in Structural Mechanics and Materials", Vol. 35, Numbers 31–32, pp. 4019–4350, John P. Dempsey and Gilles Pijaudier-Cabot, guest editors (20 papers).
2006 *Special Issue in Honor of Professor Zdeněk P. Bažant*, *Int. J. of Fracture*, Vol. 137, Numbers 1–4, pp. 1–294, G.J. Dvorak, guest editor(13 papers).
1998 *honored by a Workshop* (dedicated to Bažant's *60th birthday*) on Mechanics of Quasibrittle Materials sponsored by Electricité de France at Czech Techn. University, Prague, chaired by Z. Bittnar, G. Pijaudier-Cabot and B. Gérard (with dedicated Proc. volume).
2007 *honored by a Symposium* on Microplane and Multiscale Models at ECCOMAS Thematic Conference on Mechanics of Brittle Heterogeneous Materials in Prague, and pre-conference *ZPB70 Workshop* (at 70th birthday).
2007 *Asian Workshop in Honor of Bažant's 70th Birthday*, 1st Annual Meeting of Taiwan Concrete Institute, National Taiwan University, Taipei.

engineering and mechanics of concrete"

[17]Cited for "brilliant developments in mechanics of materials, thermodynamics of creep and stability theory, bridging experimental and theoretical research".

[18]"In recognition of lifelong successful scientific research"

[19]Cited for "fundamental research contributions".

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[21]Cited for "research on creep, inelasticity and moisture effects in concrete, nonlinear and time-dependent structural behavior, stability and fracture".

[22]One of the original top 100 in engrg.; www.ISIhighlycited.com.

[23]cited for 'many important and lasting contributions in the mechanics of solids and structures, including the theory of scaling of quasibrittle materials, constitutive equations, and stability problems of fracture, damage and inelastic behavior'

2012 *Symposium in Honor of Bažant's 75th Birthday*, at ASCE Annual Engineering Mechanics Institute Conference, University of Notre Dame, South Bend, IN

2012 *Symposium in Honor of Bažant's 75th Birthday*, "From Nanopores to Large Structures: A Life Journey across Length Scales", Society of Engineering Science Annual Meeting, Georgia Institute of Technology, Atlanta, Oct. 10, 2012.

2013 *Symposium in Honor of Bažant's 75th Birthday*, 3rd Int. Conf. on Computational Fracture Mechanics (CFRAC-3), Prague, June 6–7.

2013 ConCreep-9 (Int. Conf. on Creep, Shrinkage and Durability of Concrete Structures), named "Tribute to Prof. Bažant"

1991 *Government Lectureship Award*, National Science Council, Republic of China (Taiwan).

1978–79 *Guggenheim Fellowship.*

1996 *JSPS Fellowship*, Japan Soc. for Promotion of Science.

1988 *NATO Senior Guest Scientist Fellowship*, France.

1987 *Kajima Foundation Fellowship*, University of Tokyo.

1967-68 *Ford Science Foundation Fellowship.*

1976 Other: *Outstanding New Citizen*, from Metropolitan Chicago Citizenship Council.

Editor (in-Chief):

Journal of Engineering Mechanics, ASCE, 1988–94.

Editor:

•*Regional Editor (U.S.)*, Intern. Jour. of Fracture (Springer), 1991–.

•*Editor*, Cement and Concrete Research (Pergamon Press, later Elsevier), 1970–2006.

•*Editor*, Materials and Structures (RILEM, Paris), 1981–93; *Board Member*, 1993–2003.

•*Associate Editor*, Applied Mechanics Reviews (ASME), 1987–95, 2007–.

•Sice 1974, on editorial or advisory boards of 38 journals.

Society President and Committees

- *President*, Society of Engineering Science, 1993 (*Board of Directors*, 1988–92, 1984).
- *President and Founder*, Intern. Assoc. for Fracture Mechanics of Concrete Structures (IA-FraMCoS) 1991–93 (Board of Directors, 1991–2004), *Honorary President 2004-*.
- *President and Founder*, Intern. Assoc. for Concrete Creep and Durability (IA-ConCreep), 2001 (Board of Directors, 2001-08).
- *Chairman*, Division H, Concrete Structures, Intern. Assoc. for Structural Mechanics in Reactor Technology (SMiRT), 1981–87, 1989–94.
- *Member*, U.S. National Committee on Theoretical and Applied Mechanics, 2000–2003.
- *Chairman* of eight technical society committees in ASCE and RILEM during 1975–2015 (and member of about twenty).

PUBLICATIONS

> 622 research papers in refereed journals (since 1958), plus 52 state-of-art review papers, 234 proceedings papers, 2 short course lecture notes published as books, 20 edited books, and 9 scientific/technical books:

1. Bažant: *Creep of Concrete in Structural Analysis* (in Czech). SNTL, Prague 1966 (186 pp.).
2. Bažant and L. Cedolin: *Stability of Structures: Elastic, Inelastic, Fracture and Damage Theories*, Oxford Univ. Press, New York 1991, 2nd ed. Dover Publ., N.Y. 2002; 3rd ed. World Scientific Publ. 2010 (1009 pp.).
3. Bažant and M.F. Kaplan: *Concrete at High Temperatures*, Longman (Addison-Wesley), London 1996 (424 pp.).
4. Bažant and J. Planas: *Fracture and Size Effect in Concrete and Other Quasibrittle Materials*, CRC Press, Boca Raton and London 1998 (638 pp.).
5. M. Jirásek and Bažant: *Inelastic Analysis of Structures*, J. Wiley & Sons, London and New York 2002 (753 pp.).
6. Bažant: *Scaling of Structural Strength.* Hermes Penton Science, London 2002 (293 pp.) (French transl. 2004); 2nd updated ed. Elsevier 2005.
7. Bažant and Jia-Liang Le: *Probabilistic Mechanics of Quasibrittle Structures: Strength, Lifetime and Scaling*, Cambridge University Press 2017 (302 pp.).
8. Bažant and M. Jirásek *Creep and Hygrothermal Effects in Concrete Structures*, Springer 2018 (921 pp.).
9. *In press*: Bažant, Z.P., Le, Jia-Liang, and Salviato, Marco , *Quasibrittle Fracture Mechanics and Size Effect: First Course.*, Oxford University Press, U.K 2021 (302 pp.).

PATENTS: 5 in total.

Latest: **US Patent 10,416,053**, Sept. 7, 2019, Grips for a linear fracture testing machine and method of designing same.

In 1959: **Czechoslovak Patent 97175**, June 5, 1959, Release ski binding (one of the earliest, mass-produced, exhibited in New England Ski Museum, Franconia, NH);

MAIN SCIENTIFIC ADVANCES

• Discovery, with theoretical and experimental justification, of non-statistical (or energetic) size effect in fracture of solids (1976, 1984, 1987, 1991, 1996, books 1998 and 2005), derived by asymptotic matching. Later extended to combined statistical-energetic size effect derived from nanoscale (1996, 2000, 2004, 2007, book +2018) and recently to plastic-hardening metals [5, 13 , 2, 3]

• Development of the size effect method for measuring the fracture energy and fracture process zone size in quasibrittle materials [13, 2], also derived by asymptotic matching, and recently extended to fracture (HRR theory) of plastic hardening metals. It became International Standard Recommendation TC89-FMT of RILEM (Paris), endorsed also by ACI-446 (extension to plastic-hardening metals proposed recently).

• Comprehensive nanomechanics and thermodynamics based theory of creep and hygrothermal effects in concrete, taking into account solidification due to hydration and nanoscale stress relaxation over hours-to-century time range (1969, 1972, 1995, book 2018), with related theory of drying with diffusivity dependent on pore humidity for normal add high temperatures (1972, 1984, book 1996), and with explanation of Picket effect in creep (1972, 1994, and 2018 via MD) [19, 9, 6, 8].

• Introduction of material characteristic length and nonlocal concepts into continuum theory of quasibrittle damage and failure (1976, 1984, 1987; books 1991, 1998, 2002

and 2005) [11, 2, 4, 7, 15, 3]

• Development of the crack band model (1983) and microplane constitutive law for softening damage and quasibrittle fracture in concrete, fiber composites, and rocks (esp. shale). It is the simplest way introduce the effect of material characteristic length and the consequent nonlocality [1, 3, 7]

• Prediction of high temperature effects on concrete, creep, pore water diffusion, based on thermodynamics, with application to tunnel and other fires and nuclear reactor accidents [8]

• Development of Gauss-Weibull distribution with justification from molecular transition-rate theory (2007) with implications for size effect and structural lifetime (book 2019), justification of tail with 10^{-6} probability by size effect, and with recent extension named "fishnet" statistics for materials modeled by alternating series and parallel links. While the structural strength statistics has generally been based on statistics of loads or elastic random vibrations, Bažant has been a pioneer in deriving the tail probability of failure from the material architecture. [20]

Further consequential scientific results: • Physical-mathematical model for predicting corrosion of steel in concrete in presence of chloride ions [14]. • Solidification theory which put on solid foundation the effect of chemical (hydration) aging on concrete creep [19]. • Solved the 3D singular stress field at the intersection of crack front edge with body surface and showed that the edge of a growing crack must be non-orthogonal to the surface [17]. • Found a more efficient optimal Gaussian numerical integration formula for the surface of a sphere, use in microplane model, radiation physics, etc. [18, 16]. • Inducement of branching of hydraulic fractures if shale for gas and oil extraction • Gauss-Weibull distribution for predicting the tail risk (one in a million, 10^{-6}) of failure of quasibrittle structures—concrete, fiber composite, ceramics. • Fishnet statistics to capture the effect of alternating series and parallel links on tail risk of printed biomimetic microstructures. • Energy absorption in composite crush cans of cars under impact (funded by Chrysler and Ford). • Penetration of projectiles through concrete walls damped by release of kinetic energy of strain-rate field in finite particles. • Multi-decade prediction of concrete drying, creep, moisture and temperature effects, cracking damage and long-term degradation. • Thermodynamics of creep effects due to nanopore fluid adsorption. • Creep closing of natural cracks in rocks under millions of years of tectonic stress. • Size effects in fracture of sea ice, triggering of snow avalanches, in shear failure of RV beams. • Localization instability of softening damage. • He pioneered the filtering of statistical bias from huge databases collected from uncoordinated worldwide testing of concrete failure, creep and shrinkage. • Stability and path bifurcation of crack systems. • Thermodynamic criteria for stable post-bifurcation equilibrium path in inelastic structures. • Recently he derived statistically the HRB sorption isotherm for multilayer molecular adsorption in nanoporous solids (overcoming limitations of the BET isotherm) in which the probabilities of condensation and evaporation of molecules decrease with the number of layers due to reduction of vapor exposed surface during gradual filling of nanopores.

ENGINEERING IMPACT OF BAŽANT'S SCIENTIFIC ADVANCES

• The Bažant size effect law on the strength of concrete and other quasibrittle structures, which he discovered in 1984, is now embodied in the ACI design code (ACI Standard 318/2019). Thus all large reinforced concrete structures must be designed using the Bažant law. It is also widely used for aircraft composites, e.g., at Boeing, Airbus, as well as rocks, sea ice, rigid foams, etc. The American design code (ACI Standard 318) became the first design design code ever that is based on fracture mechanics and thus rests on solid theoretical foundation.

• His size effect method [13] of testing the fracture energy of quasibrittle materials has been since 1990 an International Standard Recommendation for concrete and rock (RILEM TC-69) and became the main method for testing the fracture energy and process zone size of concrete, rocks and composites. He recently extended the size effect law to metals with a large hardening yielding zone which led him to formulate a new simple method to measure the fracture energy (or toughness) of metals.

• His model B3 (1995) and model B4 (2015) became International Standard Recommendations TC-107-GCS and TC-242-MDC of RILEM (Paris) for creep and durability assessments of large concrete structures, and were endorsed by ACI-209 [6]. These models corrected gross underestimation of long-time creep have been used to design against excessive deflections and cracking which endanger infrastructure sustainability (if the currently inadequate lifetimes of all concrete infrastructure could be doubled, it would halve the CO_2 emissions from cement production which are about to surpass those of all the cars and trucks in the world).

• His diffusion model for drying and moisture movement in concrete [9] became standard, and is embedded in the European *fib* Model Code 2010 and Eurocode. It accounts for a two-orders of magnitude drop in diffusivity with decreasing relative humidity in micro- and nano-pores (re CO_2—ditto);

• His AAEM method for creep analysis of concrete structures [9], discovered in 1972, became an ACI-209 standard recommendation and is prescribed by European fib Model Code. It bypasses solution of integral equations to capture in a simple way the aging effect on concrete due to multidecade chemical process of cement hydration and local stress relaxation in nanostructure (re CO_2—ditto).

• His crack band model for damage and fracture of concrete (1983) [1, 2, 13] became standard in cracking and fracture assessments of large concrete and geotechnical structures, as well as safety checks of fiber composite airframes (e.g., Boeing). It is also embedded in various commercial softwares (including ATENA, DIANA, OOFEM, ABAQUS, etc) (re CO_2—ditto).

• His "microplane" material model [16] for cracking damage became a standard component of computer codes; e.g., of ANSYS - a general purpose software for damage and failure analysis of structures; of commercial concrete analysis and design softwares ATENA, DIANA; of EPIC, PRONTO wavecodes used the U.S. defense labs for analyzing the effects of missile impact and explosions on defense concrete structures. His microplane model for jointed rock is featured in commercial software (e.g., ANSYS) (re CO_2—ditto).

• Recently, with several co-workers, he explained mathematically why, in contrast to concrete, the stiff testing frames did not suffice to observe postpeak softening in fracture of fiber composites. He discovered that the stiffness of the standard specimen grips was insufficient, by far (which was overlooked since the 1960s). This led to a new grip design (US Patent 10,416,053). Tests then finally documented the existence of gradual postpeak softening in composites and thus removed a fifty-year old objection to using fracture mechanics for composites.

• His recent invention (with coworkers) of the "gap test" revealed an unexpected major effect of crack-parallel stresses on material fracture energy of quasi brittle materials. The practical impact rules out the line crack models and show the necessity of modeling fracture process zone of a finite width with a tensorial damage law as in crack band model.

Several of the foregoing scientific results significantly impacted infrastructure engineering. Additionally He explained and documented the role of size effect in the structural collapses in earthquakes in California and Japan, and in shear failures of various bridges (which was one point that influenced the ACI Committees to adopt Bažant's law for the design code).

20 SELECTED HIGHLY CITED PUBLICATIONS[24]

[1] Bažant, Z.P., and Oh, B.-H. (1983). "Crack band theory for fracture of concrete." *Materials and Structures* (RILEM, Paris), 16, 155–177 (as of Jan. 2021: 4210 cit.).

[2] Bažant. Z.P., and Planas, J. (1998). *Fracture and Size Effect in Concrete and Other Quasibrittle Materials.* CRC Press, Boca Raton (monograph, reference volume and textbook, 616 pp.) (3380 cit.).

[3] Bažant, Z.P., and Cedolin, L. (1991). *Stability of Structures: Elastic, Inelastic, Fracture and Damage Theories*, Oxford University Press, New York; 2nd. ed. Dover Publications, New York 2003 (1011 pp. + xxiv pp.); 3rd ed. World Scientific Publishing, Singapore–New Jersey–London 2010. (2820 cit.)

[4] Pijaudier-Cabot, G., and Bažant, Z.P. (1987). "Nonlocal damage theory." *J. of Engrg. Mechanics*, ASCE 113 (10), 1512–1533 (2280 cit.).

[5] Bažant, Z.P. (1984). "Size effect in blunt fracture: Concrete, rock, metal." *J. of Engrg. Mechanics*, ASCE, 110 (4), 518–535 (1920 cit.).

[6] Bažant, Z.P., and Baweja, S. (1995), in collaboration with RILEM Committee TC 107-GCS, "Creep and shrinkage prediction model for analysis and design of concrete structures—model B3 (RILEM Recommendation 107-GCS). *Materials and Structures* (RILEM, Paris) 28, 357–365 (1290 cit.)

[7] Bažant, Z.P., and Jirásek, M. (2002). "Nonlocal integral formulations of plasticity and damage: Survey of progress." *ASCE J. of Engrg. Mechanics* 128 (11), 1119–1149 (1270 cit.).

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ACTIVISM IN PROMOTING SCIENCE

He campaigned against the practice of sealing of technical data after court litigation of structural collapses (such data are invaluable for progress). In his plenary at the 2008 Structural Engineers World Congress, he successfully proposed a resolution that the data from the tragic 1996 collapse of the KB Bridge in Palau must be unsealed, in the interest of scientific progress. This prestressed box girder of world record span deflected by 1.61 m during 18 years of service. He then explained the deflection by showing the American and European specifications for multidecade creep to be inadequate. Subsequently he formed a RILEM committee which collected data on 71 bridges exhibiting similar excessive deflections. This prompted a major change in American and European design specifications for multidecade creep. He has also campaigned in ASCE and ACI, so far with only limited success, to include in their ethics codes that that it is unethical for an engineer to agree in a legal settlement to the sealing of technical data from structural disasters. In the aftermath of the WTC Towers collapse in New York, his analysis provoked formation of ASCE committee to study new designs preventing progressive collapse. He also clarified why ancient towers in Italy collapse after 700 years of placid existence, showed (with Ferretti) that the collapse of Pavia Tower was due to the 600-year drying halftime of its 3m thick walls. Noting that the failure frequency of very large structures has historically been 10^{-3}, he argued in societies for ways to achieve failure probability 10^{-6}, the maximum generally considered tolerable. For 25 years, he successfully promoted switching design of fiber composite structures from strength to fracture criteria. He has been trying to convince FE software firms such as ABAQUS to correct their objective stress rates that led, in rare but consequential cases, to major violations of energy conservation. In engineering and professional societies, he campaigned, with some success, to enforce design specifications aimed for century-long durability, lowering CO_2 imprint. Based on his recent discovery of the gap test, he now campaigns for switching

from line-crack models to tensorial models with finite crack front width. The 2021 international conference on poromechanics (a series originated in Paris), was named "Biot-Bažant" Conference. Bažant is active in the NAS Committee on Human Rights. He is the only registered structural engineer in the NAS. In his native Czechia he is known for designing in 1961, before computer age, one bridge of historical interest—the first prestressed box girder of very high horizontal curvature (30° per span), in Kořenov over Jizera river.

LECTURES, EDUCATION, CONFERENCES

111 plenary lectures at major conferences.

52 distinguished, named or endowed lectures.

He graduated 61 PhDs at Northwestern University (3 of them black0); 3 female). Also supervised dissertations of 15 students who got PhD.'s at other universities.

Education of Minorities: 3 of his PhD students were black (one became a full professor at IIT, Chicago, one an Associate Partner at SOM, a major Chicago firm, one President of his architectual firm), 5 females (one is a faculty at UC Boulder, one is a chief engineer for the City of Chicago, one went to industry), and 1 a hispanic (who became President of WJE, Denver).

Visiting professor, visiting scientist or endowed visiting chair at 17 universities around the world.

Taught 10 short courses at various universities around the world.

Organized 7 international conferences and 8 international workshops

Honored by conferences and symposia named in his honor, and by special issues at his 60th, 65th, 70th, 75th and 80th birthdays, and upon receiving various medals.

Taught 17 different courses at Northwestern since 1969.

RESEARCH GRANTS, CONTRACTS

74 Grants and Contracts since 1970 from NSF, ONR, AFOSR, ARO, DoE, DoT, EPRI, DARPA, DNA, DTRA, FAA, CRC-ACI, Boeing Co., Chrysler Corp. (USCAR), Ford Motor Co., Oak Ridge National Laboratory, Los Alamos Nat. Laboratory, U.S. Army Corps of Engineers (WES), ERDC, RANN, Sandia Laboratories, ARPA, RCRC, Shimizu Corp. (Tokyo), Korea Electric Power Institute, KAIST Korea, Cirrus Aircraft Corp.

CONSULTANT

– Argonne National Laboratory (staff consultant, 1974-94) – Oak Ridge National Laboratory – Sargent & Lundy, Chicago – ETA Corp., Chicago – Teng & Associates, Chicago – Ontario Hydro, Toronto – Swedish Cement & Concrete Institute (CBI) – WES (U.S. Army Corps of Eng.), Vicksburg – Sandia National Laboratory, Albuquerque – Portland Cement Association, Skokie – Babcock & Wilcox, Pittsburgh – Systems, Science & Software, La Jolla, CA – W.R. Grace, Columbia, MD – U.S. Forrest Products Laboratory, Madison – EPRI (El. Power Res. INst.) – MGM Engineers, Pittsburgh – Euratom, Ispra, Italy – Quadrio, Milano – Institut für Werkstoffe im Bauwesen, Stuttgart University – Institut für Statik und Dynamik, Stuttgart University – Det Norske Veritas, Oslo – Analysis & Technology, Inc. – KAIST & Hyunday Corp., Korea – KEPRI (Korea El. Power Inst.), – Taisei Corp. (Tokyo) – Červenka Ltd. (Prague) – DTRA (Washington D.C.) – Boeing Co. – Los Alamos Nat. Lab. – ES3, San Diego, and other.