DETAILED BIOGRAPHICAL RESUME OF ZDENĚK P. BAŽANT

February 20, 2007

PERSONAL: Born Dec. 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.
E-mail: z-bazant@northwestern.edu.
www.civil.northwestern.edu/people/bazant.html

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 (since 1971).

PROFESSIONAL POSITIONS

Bridge Engineer, Dopravoprojekt (State Consulting Firm), Prague, Jan. 1961–Jan. 1964.

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

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

Research 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), Argonne National Laboratory, 1974–94.

Walter P. Murphy Professor of Civil Engineering and Materials Science (a distinguished chair endowed in 1942 by W.P. Murphy), Northw. University, 1990–.

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 Engrg. and Materials, Northwestern University, 1974–1978, 1992–96.

HONORS

2002 elected **Member, National Academy of Sciences, Washington, D.C.**[1]

1996 elected **Member, National Academy of Engineering, Washington, D.C.** [2]

2008 elected **Fellow, American Academy of Sciences and Arts**, Boston.

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

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

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

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

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

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]

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

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

1997 **Honorary Doctorate (Dr.-Ing.E.h., Doktor-Ingenieurs Ehrenhalber))**, Universität Fridericiana (Technische Hochshule) Karlsruhe, Germany (conferred May 28, 1997, ceremony March 23, 1998)[5].

1991 **Honorary Doctorate (Dr. h.c.)**, Czech Technical University in Prague (ČVUT), Nov. 14[6].

2007 **Honorary Member, ASCE** (Am. Soc. of Civil Engrs.)

2005, *Theodore von Karman Medal*, ASCE (Am. Soc. of Civil Engrs.).[7]

1996, *W. Prager Medal*, Soc. of Engng. Science (SES).[8]

1997, *W.R. Warner Medal*, ASME (Am. Soc. of Mechanical Engrs.).[9]

[1] 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."

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

[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..."

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

[5] "In recognition of outstanding accomplishments in the field of building materials and structural engineering"

[6] cited for "important scientific contributions to 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] The Medal "honors outstanding contributions to the permanent

1996 *Newmark Medal*, ASCE.[10]

1997 *J.J.R. Croes Medal*, ASCE.[11]

2003 *Lifetime Achievement Award*, from ASCE Illinois Structural Engineering Section.

1993, *Medal of Czech Society for Mechanics*[12], Prague (čestná medajle České společnosti pro mechaniku).

1990, *Torroja Gold Medal* from Building Research Institute of Spain.[13].

1975 *L'Hermite Medal* from RILEM[14] (in 1975 called RILEM Medal).

2007 *Zdeněk Bažant Medal* (1st recipient of), Czech Techn. University, Prague (ČVUT) (medal named after grandfather, professor of structural mechanics and rector (i.e. president) of ČVUT)[15].

1998 *Šolín Medal*, Czech Technical University, Prague (ČVUT)[16]

1999 *Stodola Gold Medal*, Slovak Academy of Sciences, Bratislava.

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 (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 [17]

2001– *ISI Award of "Highly Cited Scientist"* [18], in engineering (www.ISIhighlycited.com).

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).

1990 *Alexander von Humboldt Award of Senior U.S. Scientist*, from Federal Republic of Germany.

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.).

The 2006 *Mindlin 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".

2004 elected *Honorary President*, IA-FRAMCOS (Int. Assoc. of Fracture Mech. of Concr. Str.)

1982 *IR-100 Award* (with S. Meiri), from Industrial Research and Development, for developing a new triaxial-torsional high-temperature testing machine.

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 *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).

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 Fellowhip*, France.

1987 *Kajima Foundation Fellowship*, University of Tokyo.

Honorary Member:

• 1991 Building Research Institute of Spain. • 1991 Czech Society of Civil Engineers. • 1993 Czech Society of Mechanics (Česká společnost pro mechaniku). • 2005 Czech Concrete Society (Česká betonářská společnost).

Endowed, Named, Distinguished Lectures:

2006 *Mindlin Lecture*, US National Congr. of Theor. & Appl. Mech., Boulder, CO.

2005 *Professor C.S. Krishnamoorthy Memorial Lecture*, Indian Institute of Technology Madras, Chenai.

2005 *Carroll Memorial Lecture*, Engineering Society of Baltimore.

2005 *Beyer Distinguished Lecture*, University of Houston.

2002 *Gurley Lecture*, Rensselaer Polytechnic Institute, Troy, N.Y.

2001 *D.M. Roy Lecture*, Am. Ceramic Society Annual Meeting, Indianapolis.

1994 *Lecturer, Southwest Mechanics Lecture Series.*

1991 *2nd International Torroja Lecture*, National Council for Scientific Research, Madrid.

1990 *Inaugural Lecture* of Walter P. Murphy Professorship, Northwestern University.

1987 *Kajima Foundation Lecture*, University of Tokyo.

1982 *Special University Lecture* of University of London in Civil and Mechanical Engineering, Imperial College, London.

1982 *11th Arthur J. Boase Lecture*, University of Colorado,

Elected Fellow:

American Academy of Mechanics (1978), Society of Engineering Science[19] (1979), RILEM (Paris, 1977), ASME (1989), ASCE

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."

[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]For the paper "Is No-Tension Design of Concrete and Rock Structures Always Safe?—Fracture Analysis," J. Struct. Eng. 122, Jan. 1996, 2–10.

[12]"For advances in mechanics."

[13]Cited for "outstanding achievements in the fields of structural engineering and mechanics of concrete"

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

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

[16]Cited for "fundamental research contributions".

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

[18]Meaning: among 250 most cited authors worldwide in engineering (all fields combined).

[19]cited for 'many important and lasting contributions in the mechanics of solids and structures, including the theory of scaling of

(1983), ACI (1979); Czechoslovak Society of Arts and Sciences (Washington, D.C., 2003).

Other:

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

1967-68 *Ford Science Foundation Fellowship.*

1966-67 *French Government ASTEF Fellowship.*

1964 *Second Prize* in Public Anonymous Competition on Danube Bridge Design, Czechoslovakia.

1958 & 1960 *National Winner* (twice), Student Research Competition in Civil Engineering, Czechoslovakia.

1955 *National Winner, Mathematical Olympics* (for high school students), Czechoslovakia.

Listed: Who's Who in America (since 1977), etc.

EDITORIAL BOARDS

Editor (in-Chief):

1. *Journal of Engineering Mechanics, ASCE*, 1988–94.

Board Member Handling and Accepting Papers:

2. *Regional Editor (U.S.)*, Intern. Jour. of Fracture (Kluwer Academic Publ.), 1991–.
3. *Editor*, Cement and Concrete Research (Pergamon Press), 1970–.
4. *Editor*, Materials and Structures (RILEM, Paris), 1981–93; *Board Member*, 1993–.
5. *Associate Editor*, Jour. of the Engrg. Mechanics Div., ASCE, 1973–77 and 198l–83.
6. *Associate Editor*, Applied Mechanics Reviews (ASME), 1987–95, 2007–.

Editorial Board Member:

7. Intern. J. of Numerical Methods in Engineering (J. Wiley), 1990–.
8. Archive of Appl. Mech. (Ingenieur-Archiv) (Springer, Berlin), 1990–.
9. Intern. J. of Numerical and Analytical Methods in Geomechanics (J. Wiley), 1979–.
10. Probabilistic Engineering Mechanics (Elsevier), 1986–.
11. Engineering Computations (Pineyard Press), 1987–.
12. Intern. J. of Damage Mechanics (Technomic Publ. Co.), 1992–.
13. Acta Mechanica (Springer), 1995–.
14. ASCE J. of Aerospace Engrg., 2002–.
15. Journal of Geomechanics ASCE, 2003– (formerly Intern. J. of Geomechanics, CRC Press, 2001–2003).
16. Acta Mechanica Sinica, 2001–.

Other: 17. Advances in Structural Engineering—An Intern. J. (Multi-Science Publishing, Ltd., U.K.), 1996–2000. • 18. Int. J. of Computational Civil and Structural Engineering (Begell House. N.Y.), 1999–. • 19. Computer Modeling in Engineering Sciences (Sage Science Press), 1999–. • 20. International Journal of Structural Stability and Dynamics (Elsevier), 2001–. • 21. Dam Engineering (Wilmington Publishing, UK), 1992–. • 22. Mechanics of Advanced Materials and Structures (Taylor & Francis), 2002–. •23. Interaction and Multiscale Mechanics: An International Journal (IMMIJ). 2008– . • 24. Multiscale Computational Modeling (Begell House, New York), 2003–. • 25. Inernational Journal of Materials and Structural Reliability (Rangsit University, Thailand, publ.), 2003–. • 26. Computers, Materials & Continua (Tech Science Press, Encino, CA), 2004–. 27. J. of Zhejiang Univ. SCIENCE, 2004–.

Formerly: 27. Nuclear Engrg. and Design (North Holland), 1990–2001. • 28. Int. J. of Cohesive-Frictional Materials and Structures (J. Wiley) 1995–2000. • 29. J. of Advanced Cement-Based Materials, 1993–98 • 30. Archives of Mechanics (Sijthoff & Noordhoff), 1980–1990. 31. FRAGBLAST—The Intern. Quarterly J. for Blasting and Fragmentation (Balkema), 1996–2004.

COMMITTEES AND SOCIETIES

- *President*, Society of Engineering Science, 1993 (*Board of Directors*, 1988–94).
- *President and Founder*, Intern. Assoc. for Fracture Mechanics of Concrete Structures (IA-FraMCoS, headquarters in Evanston, IL), 1991–93 (Board of Directors, 1991–2004).
- *President and Founder*, Intern. Assoc. for Concrete Creep and Durability (IA-CONCREEP), 2001 (Board of Directors, 2001-).
  • *Chairman and Founder*, ACI Comm. 446, Fracture Mechanics, 1985–92.
- *Member*, U.S. National Committee on Theoretical and Applied Mechanics, 2000–, resigned 2003.
- *Chairman*, Division H, Concrete Structures, Intern. Assoc. for Structural Mechanics in Reactor Technology (SMiRT), 1981–87, 1989–94 (and *Division Advisor*, 1994–96).
- *Chairman*, Division Q, Concrete and Nonmetallic Materials, ibid., 1987–89.
- *Chairman*, ASCE Engrg. Mech. Div. Programs Committee, 1989–91.
- *Chairman*, ASCE Committee on Properties of Materials (Eng. Mech. Div.), 1975–77, 1981–83.
- *Chairman*, RILEM Comm. TC107, Prediction of Creep & Shrinkage of Concrete, 1988–2000.
- *Chairman*, RILEM Comm. TC69, Math. Models for Creep & Shrinkage of Concrete, 1981–88.
- *Chairman*, RILEM Comm. TC-QFS, Size effect and scaling of quasibrittle fracture, 1994–.
- *Chairman*, Committee on Corporate Relations, Soc. of Engrg. Science, 1989–91.
- *Member of Council*, Czechoslovak Society for Arts and Sciences (SVU, Společnost pro vědy a umění), Inc., Maryland, 2002–.
- *ACI Representative* at European Concrete Institute (CEB) Comm. on "Time-Dependent Deformations of Concrete", 1971–80.
- *Member*, Task Committee of National Academy of Engineering on Status of Cement & Concrete R & D in the U.S., 1977–80.
- *Member*, Advisory Committee of National Academy of Engineering on Reinforced Concrete Floating Marine Structures, 1979-83.
- *Member* ACI Committee 209, Creep and Shrinkage in Concrete, 1970–. *Chairman*, Subcommittee 1 on Creep Mechanisms, 1970–75; *Chairman*, Subcommittee 2 on Creep Prediction, 1988–.
- *Member* Joint ASCE-ACI Comm. on Finite Element Analysis of R.C. Structures, 1979– (*Chairman*, Subcom. 5 on Time-Dependent Effects, 1979–85; *Chairman*, Subcom. on Fracture Mechanics, 1989–).
- *Member* of the NAS Committee on Human Rights, 1996–.
- *Member* of the Science Council, Czech Techn. Univ. Prague, 2005–. National Taiwan University of Science and Technology, 2007–.
- *Member* International Code Council (ICC), 2007–.
- *OTHER*: *NSF Charter Panelist*, 1990–. ASCE-EMD Committee on Probabilistic Methods, 1984–88; ASCE-EMD Comm. on Structural Stability, 1989–; Joint ASCE-ACI Comm. 334 on Shell Design, 1977–1986; ACI Comm. 348 on Struct. Safety, 1985–93; ACI Comm. 231 on Concrete at Early Ages, 1994–; ACI Comm. 445 on Shear & Torsion, 1994–; ASME-AMD (Applied Mechanics Div.), Comm. on Fundamental Research, 1975–78; ASME-AMD Comm. on Constitutive Relations 1984–; ASME Materials Div. Ceramics Comm., 1994–; SEM (Society for Experimental Mechanics) Committee on Fracture Mechan-

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quasibrittle materials, constitutive equations, and stability problems of fracture, damage and inelastic behavior'

ics, 1986–; RILEM Committee TC50 on Fracture Mechanics of Concrete, 1979–85; RILEM Committee on Rheology of Young Concrete, 1976–82; RILEM Comm. TC89 on Applications of Fracture Mechanics, 1987–91; RILEM Comm. TC90 on Fracture of Concr. 1987–93; RILEM Comm. TC148-SSC on Strain-Softening 1992–; RILEM Comm. TC114 on Computer Models for Creep & Shr., 1988–; RILEM Comm. TC123 MMC, 1993–; RILEM Comm. on Creep Data Bank, 1994–; RILEM Comm. TC-SOC 2001–; SES (Soc. of Engrg. Science) Awards Committee, 1989–83; SEAOI (Struct. Engrs. Assoc. of Illinois) Awards Committee, 1988–90, & judge on Best Design Award Panel, 1992; ASTM Subcomm. on Fracture Testing of Rock, 1979–82; ASTM Committee C-09 on Concrete, 1981–89, 1994–; Am. Soc. of Composites 2002–; US Nat. Assoc. of Computational Mech., 1993–; SSRC (Struct. Stability Res. Council) Comm. on Nonl. Frame Analysis; Council for High Rise Buildings and Urban Habitat: *Chairman* of Creep Committee, 1992–94. Czech Techn. Univ. Prague, member of Scientific Council, 2006–. ASTM Committee F-17 on Skiing, 1984–. Nat. Acad. of Sci. Committee on Human Rights, 1997–. ASCE-SEI Comm. on Progressive Collapse, 2006–.

PUBLICATIONS

480^{+} research papers in refereed journals (since 1958), 50 state-of-art review papers, 199 proceedings papers, 2 published course texts, 20 edited books, and 6 authored 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, N.Y. 2002 (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.

PATENTS: 4 (in 1959: one of the earliest release ski bindings, mass-produced in Czechoslovakia, exhibited in New England Ski Museum, Franconia, NH)

CITATION INDEX

...runnig at about 600 citations annually.

SOCIETY MEMBERSHIPS

– American Society of Civil Engineers, Hon. Member
– American Concrete Institute, Fellow
– American Academy of Mechanics, Fellow
– American Society of Mechanical Engineers, Fellow
– American Institute of Aeronautics and Astronautics
– RILEM (International Union of Research Laboratories in Materials and Structures, Paris), Fellow

Also *Member:* NAS, NAE, Austrian, Italian, Lombard and Czech Academies, FraMCoS (Int. Assoc. of Fracture Mech. for Concr. & Concr. Str., Founder), Society of Engineering Science, American Ceramic Society, American Society for Testing Materials, IABSE (International Association for Bridge & Structural Engineering), Society for Experimental Mechanics, Amer. Soc. of Composites, International Association for Structural Mechanics in Reactor Technology, Int. Soc. for Computational Mechanics, International Society of Soil Mechanics & Foundation Engineering, Structural Engineers Association of Illinois, Earthquake Engineering Research Institute, Materials Research Society, U.S. Committee on Large Dams, Structural Stability Research Council, Prestressed Concrete Institute, Intern. Soc. for Computational Engineering Science (founding member), Int. Assoc. for Bridge Maintenance and Safety. (Previously also: National Ski Association, Kenilworth Sailing Club, Centennial Tennis Club, Evanston Running Club, U.S. Olympic Society.)

GRADUATE STUDENT ADVISING

– At Northwestern: advisor of 50 Ph.D., 15 M.S. theses; also advised 11 Ph.D. theses defended at other universities.

LECTURES AND SEMINARS

– 75 plenary, endowed and named (distinguished) conference lectures
– 113 invited and sectional 'keynote' conference lectures
– 417 guest seminars at universities and institutes
– 331 other conference papers presented
– 18 intensive short courses at other universities & abroad

CONFERENCE CHAIRMAN/ORGANIZER

1. NSF Symposium on "Creep and Shrinkage in Concrete," Lausanne, 1980 (co-chairman with F.H. Wittmann).
2. NSF Workshop on "High Strength Concrete," Chicago, 1979 (co-chairman with S.P. Shah).
3. IUTAM Prager Symposium on "Mechanics of Geomaterials: Rocks, Concrete, Soils," Northwestern University, 1983 (chairman).
4. 4th RILEM International Conference on "Creep & Shrinkage of Concrete: Mathematical Modeling (CONCREEP-4)," Northwestern University, 1986 (chairman).
5. AFOSR Workshop on "Constitutive Relations and Modeling of Distribution Cracking, Strain-Softening and Localization", Institute for Mathematics, University of Minnesota, Minneapolis, 1987 (co-chairman with T. Belytschko).
6. France-U.S. Workshop on "Strain Localization and Size Effect Due to Cracking Damage", sponsored by NATO, Paris-Cachan, 1988 (co-chairman).
7. First International Symposium on "Fracture Mechanics of Concrete Structures" (FraMCoS1), Breckenridge, Colorado, 1992 (chairman).
8. CONCREEP-5—5-th RILEM Int. Conf. on Creep & Shrinkage of Concrete, Barcelona, 1993 (co-chairman with I. Carol).
9. Co-chairman, as ASCE-EMD Representative, Joint ASME-ASCE-SES Mechanics Conference, Charlottesville, VA (chair: C.T.Herakovitch).
10. Europe–U.S. Workshop on Damage and Fracture in Quasibrittle Structures: Experiment, Modeling and Computer Analysis, sponsored by U.S. National Science Foundation and European Union, Prague, Sept. 1994 (co-chairman).
11. SES Representative and Organizer, McNU'97—Joint ASCE–ASME–SES Mechanics Conference, Northwestern University, 1997.
12. ONR Workshop on Fracture Scaling (sponsor: Office of Naval Research), University of Maryland, College Park, 1999.
13. CONCREEP-6 (co-chairman with F.J. Ulm and F. Wittmann)—6th Int. Conf. on Concrete Creep and Durability, M.I.T., 2001.
14. NSF Workshop on Model-Based Simulation of Material Durability (co-chairman with Z. Bittnar, G. Pijaudier-Cabot and Y. Xi), Czech Techn. Univ. Prague, 2002.

RESEARCH GRANTS, CONTRACTS: 49 Grants and Contracts since 1970, totaling over $9 mil., from NSF, ONR, AFOSR, DoE, DoT, EPRI, ARO, DARPA, DNA, FAA, Boeing Co., Chrysler Corp., Oak Ridge National Laboratory, U.S. Army Corps of Engineering (WES), Los Alamos Nat. Laboratory, Sandia Laboratories, ARPA, RCRC, Shimizu Corp. (Tokyo), Korea Electric Power Institute, FAA, Cirrus Aircraft Corp., DaimlerChrysler.

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 – 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 Co. (Prague) – Boeing Co., and other.

TEACHING AT NORTHWESTERN

49 PhDs, 17 MS graduated. Courses taught: **1**. Stability of Structures **2**. Inelastic Analysis of Structures **3**. Fracture of Concrete **4**. Cohesive Fracture and Scaling **5**. Continuum mechanics **6**. Structural Analysis **7**. Advanced Structural Analysis **8**. Design of Reinforced Concrete **9**. Design of Prestressed Concrete **10**. Concrete Inelasticity **11**. Behavior of Reinforced Concrete **12**. Concrete Shells **13**. Inelastic Structural Stability **14**. Material Modeling Principles **15**. Mechanics (Statics and Dynamics) **16**. Mechanics of Materials I and II **17**. Selected Topics in Materials Science

VISITING PROFESSOR

• Swedish Cement and Concrete Institute (CBI), Royal Institute of Technology, Stockholm 1976–1977. • Chalmers University, Göteborg 1977. • Politecnico di Milano, 1982, 1993, 1996, 2000, 2002. • Swiss Federal Institute of Technology (EPFL), Lausanne 1983, 1997, 2001. • E.N.S. (Ecole Normale Supérieure), Paris–Cachan 1988, 1992, 2000. • Technische Universität München, Germany 1990, 1991. • Technische Universität Stuttgart, Germany 1991, 1992. • I.N.S.A. (Institut National des Sciences Appliquées), Lyon–Villeurbane, France, 1993. • Lulea University, Sweden, 1994. • E.T.H. (Swiss Federal Institute of Technology), Zürich 1995. • National University of Singapore, 2001.

VISITING SCIENTIST

• CEBTP (Centre d'Etude du Bâtiment et des Travaux Publics), Paris, 1966-67; • University of California, Berkeley 1968–69; again 1978; • Stanford University, 1978; • E.T.H., Zürich 1979; • California Institute of Technology, 1979; • M.I.T., 1979; • Technische Universität, Wien, 1981; • University of Cape Town, 1984; • University of Adelaide, 1985; • University of Tokyo, 1987, 1996; • Universidad Politecnica de Madrid, Spain, 1992; • Universidad Politecnica de Catalunya, Barcelona, 1994, 1999. • Lulea University, Sweden, 1994. • Laboratoire central des ponts et chaussées (LCPC), Paris, 1998. • University of Palermo, 1998.

FOREIGN LANGUAGES

Foreign languages: French (fluent), Czech (native), German, Russian (lectured in all four).

CONTRIBUTIONS TO SCIENCE

As stated in NAS citation in 2002, Bažant 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 the nonlocal and crack-band models now widely used in numerical simulations of quasibrittle failure of structures.

Up to the 1980s, all the experimentally observed size effects in solid mechanics were generally attributed to material strength randomness. He revolutionized the scaling theory beginning with his 1984 discovery of the scaling law for the size effect caused by the release of stored energy due to stable growth of large fractures or large damage zones prior to failure. Using asymptotic matching arguments, he derived a deceptively simple law of surprisingly broad applicability, bridging the power scaling laws of classical fracture mechanics and plasticity. With his assistants, he experimentally verified his law for various particulate and fiber composites, rocks, sea ice, toughened ceramics, foams, and other advanced materials, and showed how to use the scaling law to identify the cohesive fracture characteristics from new types of experiments.

To make finite element simulations of structural response exhibit the correct size effect, Bažant developed, beginning in 1976, the nonlocal damage and crack-band concepts with a material characteristic length, which overcome spurious mesh-size sensitivity and capture the localization of distributed softening damage. He then justified the nonlocality by micromechanics of interacting growing crack systems in heterogeneous materials. Later, using extreme value statistics, he formulated a probabilistic generalization describing the transition to the classical statistical size effect in very large structures failing at fracture initiation. He showed that Weibull distribution of structural strength is an inevitable consequence of Maxwell-Boltzmann distribution of atomic energies, that the strength threshold must be zero, that the strength distribution of RVE of quasibrittle material must be Gaussian with a remote power-law tail, and that this distribution must gradually change to Weibullian with increasing structure size, and demonstrated that the standard homogenization theory is inapplicable to failure of large damaging structures. Recently, he used asymptotic arguments to show that the currently accepted dislocation-based strain-gradient theory of metal plasticity for micrometer scale needs a fundamental revision because of unreasonable asymptotic properties on approach to nanoscale.

While Bažant is in science best known as a world leader in scaling research in solid mechanics, he is also known for diverse other researches in fracture mechanics, stability of structures, micromechanics of damage in materials, inelastic constitutive laws, viscoelasticity, concrete creep and shrinkage, and thermal and humidity effects on concrete. He has made contributions in plasticity, finite strain theory, probabilistic mechanics, numerical methods, and materials testing. He has been applying his research mainly to concrete and geomaterials, and more recently also extensively to fiber composites, ceramics, soils and metals. The applications spanned concrete structures, arctic engineering, geotechnical engineering, nuclear safety, load-bearing composite structures for ships and aircrafts, offshore structures, tunnel excavation, earthquake engineering, mining, hardened structures, geophysical exploration, and most recently nanocomposites and thin films.

Bažant's contributions influenced many others and received wide attention, as attested by his **citation index** (with a career total of about 7500 citations); he is an **ISI Highly Cited Researcher** in engineering (i.e., in all engineering fields combined), and his **H-index** (defined as number n of papers that received at least n citations each) is 42.

CONTRIBUTIONS TO ENGINEERING RESEARCH

In tackling the problem of scaling of failure, Bažant proved by asymptotic energetic fracture analysis, numerical simulations and by experiments in his lab that the size effect on strength of quasibrittle structures is caused mainly by energy release and can be most simply described by the law $\sigma_N = k(1+D/D_0)^{-1/2}$ (D = structure size, σ_N = nominal strength of structure; k, D_0 =const.). He showed his strikingly simple size effect law to apply to the quasibrittle failures of concrete structures (diagonal shear, punching shear, torsion, bar or anchor pullout, splices, column failures, etc.), as well as to polymer-fiber composites, rock, sea ice, toughened ceramics, wood, cellular materials and snow (avalanches), for which no size effect had previously been considered in design codes and finite element programs). He extended his size effect theory to snow avalanches and slides in clay and to sandwich plates, and demonstrated compound size effect in steel-concrete composite beams. He also extended his size effect law to compression fracture, including kink band propagation in fiber composites, and to quasibrittle structures with reentrant corners, and showed that cohesive delamination buckling in imperfect (dented) light-core sandwich plates exhibits a strong size effect. He further exploited his size effect law to develop a new, simple and unambiguous test procedure for measuring the fracture energy, process zone size and other nonlinear fracture characteristics, which was adopted as an International Recommendation of RILEM (Int. Union of Res. and Testing Lab. in Mat. and Str., Paris). He also derived and verified another surprisingly simple asymptotic size effect formula for failures at fracture initiation (e.g., modulus of rupture test). To support his arguments in committees responsible for concrete design code, he showed that the size effect must have played a role in many catastrophic structural failures and that the neglect of size effect causes the frequency of failures of large structure to drop from $\geq 10^{-6}$ to $< 10^{-3}$.

By 1975, strain-softening stress-strain relations for finite element modeling of cracking damage became standard practice; this is now generally recognized as incorrect, mainly due to Bažant's demonstration of ill-posedness, spurious mesh sensitivity and localization, and lack of size effect. Bažant's simple remedy—the energy-based crack band model—became widely used in industry and commercial codes (e.g. DIANA, SBETA, ATENA, etc.).

As a more general remedy, followed by many others, Bažant pioneered the nonlocal continuum approach to damage localization (1983, 1987) and introduced it into finite element analysis, and recently also into the boundary element method. He justified it physically by microcrack interactions. Recently, he developed (with D. Novak) a probabilistic generalization of the

nonlocal model for softening damage and by means of asymptotic matching deduced a simple size effect formula for the combined energetic-statistical size effect in quasibrittle failure, and showed its importance for large arch dams. In two recent papers in Proc. of NAS, he presented a new technique to derive size effect laws by asymptotic matching, and showed (with S. Pang) that the resistance safety factors for concrete, fiber composites and other quasibrittle structures should be varied as a function of structure size and shape because the strength distribution gradually changes from Gaussian to Weibull.

Further Bažant showed that, for quasibrittle materials, Paris' law for fatigue crack growth requires a size effect correction. He championed the fracture mechanics approach to global compression failure of concrete and rock, solving the size effects in compression failures (breakout of boreholes, mine openings), in kink-band propagation in fiber composites. He identified experimentally and analytically strong size effects in delamination of sandwich plates used in aircraft and ships. He solved the size effect on vertical load capacity of sea ice plates, and on the triggering of snow avalanches. He experimentally discovered that softening can be reversed to hardening by a sudden increase of loading rate, and explained it by activation energy mechanism. He showed that, for quasibrittle materials, the previously accepted Weibull-type statistical strength theory gives an incorrect size effect and overcame the problem by its nonlocal generalization.

Among various contributions to nonlinear constitutive modeling of concrete and geomaterials, Bažant developed the microplane constitutive model for softening damage—a powerful approach, in which the constitutive law is specified in terms of not tensors but components on planes of various orientations. He formulated effective microplane models for concrete (models M4 and M5), rock, clay, sand, steel, rigid foam, fiber-reinforced composites and shape-memory alloys. He also presented an effective nonlinear two-phase constitutive model for shear densification of saturated sand, applied in seismic liquefaction studies. Devising the novel 'tube-squash' test, he showed experimentally that under very large confining pressures (generated at the nose of penetrating missile), concrete can behave perfectly plastically, retaining integrity and sustaining without fracturing shear angles as large as 70°, and developed for such plastic response a finite-strain microplane model (used now at WES and Sandia in code EPIC, PRONTO and JAS for missile penetration predictions). Based on his tube-squash test he identified the minimum confining pressure needed to suppress softening and size effect in compression, with implications for confining reinforcement needed to improve seismic performance of concrete columns. He experimentally demonstrated the vertex effect in strain-softening concrete and showed that it is captured by microplane model.

Bazant made lasting contributions to stability theory, including the correlation of stability theories and objective stress rates associated with different finite strain measures; conditions of localization into ellipsoidal domains and layers; thermodynamics-based criterion for stable post-bifurcation path; stability criteria for frictional materials; bifurcation due to crack arrest in interacting crack systems (including parallel cooling cracks, with application to a hot-dry-rock geothermal energy project); and micropolar continuum approximation for buckling of regular lattices (e.g., space structures). He also solved the three-dimensional stress singularity and edge angle for skew crack edge–surface intersections, and (with J.D. Achenbach) the singularity of dynamically propagating cracks in orthotropic materials.

Bažant formulated a new finite strain tensor that has compression-tension symmetry (like Hencky's logarithmic strain) yet is efficient to compute (without spectral decomposition). He derived a new more efficient (9th degree) Gaussian integration formula for spherical surface (used not only in constitutive modeling, but also in computational chemistry, wave scattering and radiation studies). He demonstrated spurious wave reflection in finite element meshes due to changing element size (selected by Soc. for Exploration Geophysics for reprinting in their recent volume of most important papers). Recently, he found that only one among many possible finite strain measures leads to the correct critical loads for buckling of structures very soft in shear (e.g. sandwiches, helical springs) when the constant small-strain shear modulus is used, and showed Biot's formulae for 3D buckling soft-in-shear layered bodies need a correction.

Bažant's development in 1972 of the age-adjusted effective modulus, extending previous work of Trost, allowed approximate solution of the system of integral equations for aging creep effects in concrete structures by simple quasi-elastic analysis. This method is now standard, embodied in American (ACI 209) recommendations and European CEB Model Code, as well as in textbooks; so is his formula to predict the relaxation function of aging concrete from the creep function. Recently he developed an effective filtering method to extract statistical size effect trend from database on creep or shear strength that are contaminated by nonsystematic variation of subsidiary parameters.

His prediction model B3 for concrete creep and shrinkage (RILEM Recommendation) is considered the most accurate and realistic, and is widely used in design worldwide (also recommended by ACI Comm. 209).

As staff consultant to Argonne National Laboratory (1974-94), he also developed improved, thermodynamically-based models for creep, hygrothermal effects, pore pressure, solidification, aging and stochastic behavior of concrete in nuclear containments and vessels, later used and emulated in safety studies in various labs in Europe and Japan. His exponential algorithm for concrete creep (1971) is utilized in many finite element codes. Recently he applied these results in a study of microwave-induced rapid spalling of surface layers of concrete for the purpose of decontamination from radionuclides.

He explained the drying creep (Picket effect) by thermodynamic analysis of hindered water adsorption and relaxation of microprestress induced chemically and by adsorption in hardened cement paste. His nonlinear diffusion model for drying of concrete is widely used in computations. He also formulated a comprehensive model for salt and ion transport in concrete and for the electrochemical processes in corrosion of steel reinforcement coupled with fracturing—problems of key relevance to durability. By combined fracture mechanics and diffusion-reaction analysis of the use of waste glass in concrete, he explained an anomaly in the effect of particle size on the alkali-silica reaction. His model for coupled moisture and heat transport in concrete has been widely applied in computations for hypothetical nuclear reactor accidents and fire effects (including the 'Chunnel' fire). Bažant's model for coupled moisture and heat transport has been widely applied for analyzing hypothetical nuclear reactor accidents. Recently he showed that the recent collapses of ancient towers in Italy were caused by a long-term desiccation of thick masonry walls, engendering load transfer to stone cladding and size effect in the cladding. Bažant's contributions to creep and humidity effects and their statistical analysis are important for durability of the nation's infrastructure as well as design of more daring structures with high-performance concretes.

Combining up-to-date theories of both mechanics and probability, Bažant also pioneered probabilistic models for concrete creep and shrinkage, fracture and size effect. He developed a Bayesian prediction model and Latin hypercube sampling approach for predicting concrete creep effects (the latter used in commercial code ATENA), and for extrapolating short-time shrinkage and creep data (removing ill-conditioning of regression equations by the use of water loss data); and a spectral solution of random environmental influences in aging and drying concrete (overcoming ergodicity limitations due to aging). With coworkers he conducted statistical experimental studies and developed by far the largest statistical data bases for concrete creep and shrinkage as well as concrete fracture prediction. He showed that unrealistic safety factors in current design codes, as well as reliability indices, imply a huge, but irrational, hidden size effect. Exploiting his size effect law, he reduced the identification of nonlinear fracture parameters from experiments to linear regression. Recently he formulated a probabilistic generalization of his nonlocal numerical method for distributed fracture, conforming to the stability postulate of extreme value statistics, and showed that it exhibits the correct size effect.

During the last few years, Bažant focused attention on the scaling of thin metallic films and nanocomposites on approach to nanoscale. He showed that the strain gradient theory reigning by 2000 needed a correction to prevent unreasonable asymptotic behavior toward nanoscale (the revised theory of Gao et al., although supported by a different argument, agrees with Bažant's suggestion). Subsequently he showed that, for thin films, the scaling must also consider an epitaxially induced boundary layer on the side that was in contact with the substrate, and devised an asymptotic matching formula.

Bažant published the first explanation of the collapse of *World Trade Center* (WTC) towers. Submitted within days after the collapse, his mechanical analysis, relying on well-known principles, has stood up later scrutiny (NIST study) and was translated into seven languages. Five years later, he published a theory of progressive collapse of tall building, verified it by reported observations on WTC, and showed how it could be calibrated by monitoring building demolitions.