CURRICULUM VITAE

Name: Kenneth Alan Snyder

Citizenship: United States of America

Education: Cornell University, B.S.
Applied and Engineering Physics, 1990

University of Maryland, Ph.D.
Physics: Condensed Matter, 2005

Thesis Title: Energy Localization and Transport in Binary Isotopically Disordered Fermi-Pasta-Ulam Chains

Thesis Advisor: Prof. T.R. Kirkpatrick

Employment: 2009 – Present, Leader
Inorganic Materials Group
Materials and Structural Systems Division
Engineering Laboratory
National Institute of Standards and Technology

1990 – 2009, Physicist,
Materials and Construction Research Division
Building and Fire Research Laboratory
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Professional Societies: American Physical Society (APS)
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American Concrete Institute (ACI)

Invitations: May – August, 2001
Département de Génie Civil
Université Laval
Québec, CANADA
Host: Prof. Jacques Marchand

RESEARCH INTERESTS

Concrete Degradation Modeling: Every concrete degradation mechanism is preceded by transport and reaction within the hardened cement paste phase of the concrete. The computer program 4sight is a transport and reaction model that was developed for the U.S. Nuclear Regulatory Commission to facilitate performance assessment of underground low level nuclear waste disposal sites. 4sight incorporates the relevant physics and chemistry of acid attack, leaching, corrosion of the steel reinforcement, and sulfate attack. Furthermore, these degradation mechanisms are allowed to occur simultaneously, thereby incorporating synergistic effects.

Transport Coefficient: The 4sight transport equation separates chemical properties from physical properties. The self-diffusion coefficient and electrochemical mobility of individual ions can be found in reference books. The tortuous path ions must take through the microstructure can be characterized by the formation factor, a material parameter that characterizes the ratio of the length of the tortuous path through the microstructure to the length of the physical specimen. The formation factor can be determined independently from the ratio of the pore fluid conductivity to the bulk (pore fluid plus solid) conductivity. This single parameter can characterize diffusive transport for an arbitrary number of ionic species in solution. Ongoing experiments are being developed to validate this.

Entrained Air Void Characterization: The entrainment of small (5 μm – 300 μm) air voids in the cement paste phase of concrete is the most reliable means of ensuring that concrete can be immune to the effects of freezing and thawing. More specifically, the proper combination of total void volume and air void diameter distribution is required. Presently, the only standardized means of characterizing these parameters is the ASTM C 457 linear probe analysis of air voids in hardened cement paste and concrete. Although the test can be an accurate measure of total void volume, it yields a poor characterization of the air diameter distribution. Techniques are being developed to use ASTM C 457 data to validate the hypothesis that the air void diameter distribution is lognormal. Moreover, the technique may one day be used to distinguish between entrained and entrapped air voids, and to determine how well the ASTM C 457 test was performed.

HONORS & AWARDS

1992 American Society of Civil Engineers
Materials Engineering Division
Best Basic Research Paper
(with K. Natesaiyer and K. Hover)

1995 American Concrete Institute
National Capital Chapter
1995 Outstanding Accomplishment Award
(with L. Kaetzel and J. Clifton)

2009 National Institute of Standards and Technology (NIST)
Bronze Medal Award
(with Dale Bentz)

BOOK CHAPTERS

Stereology: "The Stereological and Statistical Properties of Entrained Air Voids in Concrete: A Mathematical Basis for Air Void System Characterization," by K.A. Snyder, K. Natesaiyer, and K.C. Hover, appears in *Materials Science of Concrete VI*, pp. 129–214, (Skalny and Mindess, editors), published by the American Ceramic Society in 2001. The chapter summarizes techniques for air void characterization: uncertainty in standard method ASTM C 457 measurements; the relationship between planar and linear probe data and the air void radius distribution; thin section data analysis; the geometrical accuracy of spacing equations; and the estimation of the protected paste volume.
ISBN: 978-1-57498-069-1

Modeling Moisture Transport: "Modeling Ion Transport Mechanisms in Unsaturated Porous Media," by J. Marchand, E. Samson, K.A. Snyder, and J.J. Beaudoin, in *Encyclopedia of Surface and Colloid Science*, published by Marcel Dekker (2002). The chapter is a thorough exposition on the application of the Richard's equation to modeling moisture transport in porous media. Specifically, it formally expresses the meaning of the field variable representing moisture content. Moreover, it formalizes ionic transport in relationship to moisture transport.
ISBN: 9780824707590

Modeling Transport and Reaction: "Modeling Degradation of Cementitious Materials in Aggressive Aqueous Environments," by P. Le Bescop, B. Lothenbach, E. Samson, and K.A. Snyder, in *Performance of Cement-Based Materials in Aggressive Aqueous Environments*, pp. 177–218, (Alexander, Bertron, De Belie, editors), published by RILEM TC 211-PAE (2013). The chapter thoroughly describes the physicochemical approach of modeling transport and reaction in cementitious materials, with an emphasis on incorporating phenomena associated with aggressive environments: multiple species, high concentrations, and moisture transport.
ISBN: 978-94-007-5413-3

JOURNAL PUBLICATIONS

1. K.A. Snyder, K.C. Hover, K. Natesaiyer, "An Investigation of the Minimum Expected Uncertainty in the Linear Traverse Technique," *Cement, Concrete, and Aggregates*,CCAGDP, **13** (1), 3–10, Summer (1991).

2. K.A. Snyder, K.C. Hover, K. Natesaiyer, and M.J. Simon, "Modeling Air-Void Systems in Hydrated Cement Paste," *Microcomputers in Civil Engineering* **6**, 35–44, 1991.

3. K.A. Snyder, E.J. Garboczi, and A.R. Day, "The Elastic Moduli of a Simple 2–D isotropic composite: Computer Simulation and Effective Medium Theory," *Journal of Applied Physics*, **72** (12), 5948–5955, Dec. 15, 1992.

4. A.R. Day, K.A. Snyder, E.J. Garboczi, and M.F. Thorpe, "The Elastic Moduli of a Sheet Containing Circular Holes," *J. Mech. and Phys. of Solids*, **40**, (5), 1031–1051, 1992.

5. K. Natesaiyer, K.C. Hover, and K.A. Snyder, "Protected-paste volume of air entrained cement paste. Part I," *Journal of Materials in Civil Engineering* **4**, 166–184, 1992.

6. K. Natesaiyer, K.C. Hover, and K.A. Snyder, "Protected-paste volume of air entrained cement paste. Part II," *Journal of Materials in Civil Engineering* **5**, 170–186, 1993.

7. D.N. Winslow, M.D. Cohen, D.P. Bentz, K.A. Snyder, and E.J. Garboczi, "Percolation and pore structure in mortars and concrete," *Cement and Concrete Research* **24**, 25–37, 1994.

8. K.A. Snyder, J.R. Clifton, and L.I. Knab, "Freeze-Thaw Susceptibility of High Performance Concrete," *Wiss. Z. Hochsch. Archit. Bauwes. (Weimar)* **40**, 139–142, 1994.

9. K.A. Snyder and J.R. Clifton, "Measures of Air Void Spacing," *Wiss. Z. Hochsch. Archit. Bauwes. (Weimar)* **40**, 155–157, 1994.

10. E.J. Garboczi, K.A. Snyder, J.F. Douglas, and M.F. Thorpe, "Geometrical percolation threshold of overlapping ellipsoids," *Phys. Rev. E.*, **52** (1), 819–828, July 1995.

11. D.P. Bentz, J.R. Clifton, and K.A. Snyder, "Predicting service life of chloride-exposed steel-reinforced concrete," *Concrete International* **18**, 42–47, (December) 1996.

12. K.A. Snyder, "A numerical test of air void spacing equations," *Advanced Cement Based Materials* **8**, 28–44, 1998.

13. D.P. Bentz and K.A. Snyder, "Protected paste volume in concrete: Extension to internal curing using saturated lightweight fine aggregate," *Cement and Concrete Research* **29**, 1863–1867, 1999.

14. K.A. Snyder and T.R. Kirkpatrick, "Influence of Anderson localization on the mode decay of excited nonlinear systems," *Annalen der Physik (Leipzig)* **8** (Special Issue) SI: 241–244, 1999.

15. K.A. Snyder, C. Ferraris, N. Martys, and E.J. Garboczi, "Using impedance spectroscopy to assess the viability of the rapid chloride test for determining concrete conductivity," *Journal of Research NIST* **105**, 497–509, 2000.

16. R. Barbarulo, J. Marchand, K.A. Snyder, and S. Prené, "Dimensional analysis of ionic transport problems in hydrated cement systems - Part 1: Theoretical considerations," *Cement and Concrete Research* **30**, 1955–1960, 2000.

17. K.A. Snyder, "The relationship between the formation factor and the diffusion coefficient of porous materials saturated with concentrated electrolytes: Theoretical and experimental considerations," *Concrete Science and Engineering* **3**(12), 216–224, 2001.

18. K.A. Snyder, X. Feng, B.D. Keen, and T.O. Mason, "Estimating the electrical conductivity of cement paste pore solutions from OH-, K+, and Na+ concentrations," *Cement and Concrete Research* **33**, 793–798, 2003.

19. E. Samson, J. Marchand, and K.A. Snyder, "Calculation of ionic diffusion coefficients on the basis of migration test results," *Materials and Structures* **36**, 157–165, 2003.

20. K.A. Snyder and D.P. Bentz, "Suspended hydration and loss of freezable water in cement pastes exposed to 90 % relative humidity," *Cement and Concrete Research* **34**, 2045–2056, 2004.

21. K.A. Snyder and T.R. Kirkpatrick, "Wave localization in binary isotopically disordered one-dimensional harmonic chains with impurities having arbitrary cross section and concentration," *Physical Review B* **70**, 104201, 2004.

22. E. Samson, J. Marchand, K.A. Snyder, and J.J. Beaudoin, "Modeling ion and fluid transport in unsaturated cement systems in isothermal conditions," *Cement and Concrete Research* **35**, 141–153, 2005.

23. K.A. Snyder and T.R. Kirkpatrick, "Energy transport along Fermi-Pasta-Ulam chains containing binary isotopic disorder: Zero-temperature systems," *Physical Review B* **73**, 134204, 2006.

24. K.A. Snyder, Z.Q. Lu, and J. Philip, "Long-term monitoring strategy for concrete-based structures using nonlinear Kalman filtering," *J. Phys. IV France* **136**, 191–200, 2006.

25. D.P. Bentz, C.-J. Haecker, M.A. Peltz, and K.A. Snyder, "X-ray absorption studies of drying of cementitious tile adhesive mortars," *Cement and Concrete Composites* **30**, 361–373, 2008.

26. D.P. Bentz, K.A. Snyder, L.C. Cass, and M.A. Peltz, "Doubling the service life of concrete. I: Reducing ion mobility using nanoscale viscosity modifiers," *Cement and Concrete Composites* **30**, 674–678, 2008.

27. D.P. Bentz, M.A. Peltz, K.A. Snyder, and J.M. Davis, "VERDiCT: Viscosity Enhancers Reducing Diffusion in Concrete Technology," *Concrete International* **31**(1), 31–36, 2009.

28. D.P. Bentz, K.A. Snyder, and M.A. Peltz, "Doubling the service life of concrete structures. II: Performance of nanoscale viscosity modifiers in martars," *Cement and Concrete Composites* **32**(3), 187–193, 2010.

29. J.W. Bullard, B. Lothenbach, P.E. Stutzman, K.A. Snyder, "Coupling thermodynamics and digital image models to simulate hydration and microstructure development of portland cement pastes," *Journal of Materials Science* **26** (4), 609–622, 2011.

30. K.A. Snyder, D.P. Bentz, and J.M. Davis, "Using viscosity modifiers to reduce effective diffusivity in mortars," *Journal of Materials in Civil Engineering* **24** (8), 1017–1024, 2012.

31. D.P. Bentz, K.A. Snyder, M.A. Peltz, K. Obla, and H. Kim, "Viscosity modifiers to enhance early-age performance and long term durability of concrete," *ACI Materials Journal* **110** (5), 495–502, 2013.

32. J. Weiss, K.A. Snyder, J.W. Bullard, and D.P. Bentz, "Using a Saturation Function to Interpret the Electrical Properties of Partially Saturated Concrete," *Journal of Materials in Civil Engineering* **25**(8), 1097–1106, 2013.

33. R. Spragg, C. Villani, K.A. Snyder, D.P. Bentz, J.W. Bullard, J. Weiss, "Electrical Resistivity Measurements in Cementitious Systems: Observations of Factors that Influence the Measurements," *Journal of the Transportation Research Board* **2342**, 90–98, 2013.

34. D.P. Bentz, J.M. Davis, M.A. Peltz, K.A. Snyder, "Influence of internal curing and viscosity modifiers on resistance to sulfate attack," *Materials and Structures* **47** (4), 581–589, 2014.

CONFERENCE PROCEEDINGS

1. A.R. Day, M.F. Thorpe, K.A. Snyder, E.J. Garboczi, "Digital-Image-Based Study of Circular Holes in an Elastic Matrix," in **Mechanical Properties of Porous and Cellular Materials**, (eds. K. Sieradzki, D.J. Green, and L.J. Gibson), Materials Research Society Symposium Proceedings, Vol. 207, 95–102, Pittsburgh, PA (1991).

2. K.A. Snyder, D.N. Winslow, D.P. Bentz, and E.J. Garboczi, "Interfacial Zone Percolation in Cement-Aggregate Composites," in **Interfaces in Cementitious Composites**, **18**, 259–268, RILEM International Conference Proceedings, Toulouse, 1992.

3. K.A. Snyder, D.N. Winslow, D.P. Bentz, and E.J. Garboczi, "Effects of Interfacial Zone Percolation on Cement-Based Composite Transport Properties," in **Advanced Cementitious Systems: Mechanisms and Properties**, Materials Research Society Proceedings, **245**, 265–270, 1992.

4. D.P. Bentz, J.T.G. Hwang, C. Hagwood, E.J. Garboczi, K.A. Snyder, N. Buenfeld, and K.L. Scrivener, "Interfacial Zone Percolation in Concrete: Effects of Interfacial Zone Thickness and Aggregate Shape," in *Microstructure of Cement-Based Systems/ Bonding and Interfaces in Cementitious Materials* Materials Research Society Proceedings, **370**, 437–442, 1994.

5. K.A. Snyder, J.R. Clifton, and J. Pommersheim, "A computer program to facilitate performance assessment of underground low-level waste concrete vaults," in, *Scientific Basis for Nuclear Waste Management XIX*, Materials Research Society Proceedings, **412**, 491–498, 1996.

6. D.P. Bentz, K.A. Snyder, P.E. Stutzman, "Microstructural modelling of self-desiccation during hydration," *Self-Desiccation and Its Importance in Concrete Technology*, Edited by B. Persson and G. Fagerlund, Proceedings of an International Research Seminar in Lund, 132–140, (June) 1997.

7. D.P. Bentz, K.A. Snyder, P.E. Stutzman, "Hydration of Portland cement: The effects of curing conditions," *Proceedings of the 10th International Congress on the Chemistry of Cement* (Vol. 2), Edited by H. Justnes, 2ii078 (8 pp.), 1997.

8. M.J. Simon, E.S. Lagergren, and K.A. Snyder, "Concrete mixture optimization using statistical mixture design methods," *Proceedings of the PCI/FHWA International Symposium on High Performance Concrete*, Edited by L.S. Johal, 230–244, (October) 1997.

9. M.J. Simon, K.A. Snyder, and G.J. Frohnsdorff, "Advances in concrete mixture optimization," (invited paper), *Creating With Concrete*, Dhir ed., 1999.

10. K.A. Snyder, "Estimating the 95-th percentile of the paste-void spacing distribution in hardened cement paste containing air entrainment," in *Frost*

Damage in Concrete, D.J. Janssen, M.J. Setzer, and M.B. Snyder (editors), 1999 RILEM Minneapolis Workshop, pp. 75–86, 2002.

11. K.A. Snyder and J. Philip, "Concrete degradation modeling in the evaluation of entombment as a decommissioning option," SPECTRUM 2002, Reno, NV, 2002.

12. K.A. Snyder, Z.Q. Lu, and J. Philip, "Long-term monitoring strategy for concrete-based structures using nonlinear Kalman filtering," International Symposium on the Corrosion and Long Term Performance of Reinforced Concrete in Nuclear Power Plants and Waste Facilities (*NUCPERF 2006*), Cadarache, France, March 2006.

13. K.A. Snyder, R.D. Mountain, and A. Faraone, "A C-S-H atomic-scale computational toolkit: Application to service life modeling," *Advances in Concrete Through Science and Engineering*, J. Marchand, R. Gagné, M. Jolin, B. Bissonnette, and F. Paradis (Editors), 2006.

14. D.P. Bentz, E.J. Garboczi, N. Martys, K.A. Snyder, W.S. Guthrie, K. Kyritsis, and N. Neithalath, "Virtual Testing of Concrete Transport Properties," ACI session on *Materials Science Modeling as a Solution to Concrete Problems* (Fall 2008).

15. K.A. Snyder, P.E. Stutzman, J. Philip, and D. Esh, "Hydrated Phases in Blended Cementitious Systems for Nuclear Infrastructure," (To Be Published) NUCPERF 2009 Proceedings, Cadarache, France, (Spring 2009).

16. D.W. Esh, J. Philip, K.A. Snyder, "Performance Assessment Insights on the use of Cements in Waste Management," AMP 2010, Toronto, Canada.

17. J.W. Bullard, B. Lothenbach, P.E. Stutzman, and K.A. Snyder, "Using Thermodynamics to Simulate Cement Paste Microstructure Development," pp. 1–8, *Concrete Modeling CONMOD'10, Proceedings of the International RILEM Symposium*, Lausanne, Switzerland, 2010.

INTERNAL REPORTS

1. K.A. Snyder, J.R. Clifton, and N.J. Carino, "Nondestructive Evaluation of the In-Place Compressive Strength of Concrete Based Upon Limited Destructive Testing," *NISTIR 4874*, National Institute of Standards and Technology, Gaithersburg, MD, 1992.

2. K.A. Snyder, J.R. Clifton "Calculating Cement Paste and Mortar Diffusivity from Conductivity Measurements: Preliminary Results Of a New Method," *NISTIR 5235*, National Institute of Standards and Technology, October 1993.

3. K.A. Snyder and J.R. Clifton, "`4SIGHT` Manual: A Computer Program for Modelling Degradation of Underground Low Level Waste Concrete Vaults," *NISTIR 5612*, National Institute of Standards and Technology, Gaithersburg, June 1995.

4. J.R. Clifton, J.M. Pommersheim, and K.A. Snyder, "Long-Term Performance of Engineered Concrete Barriers," *NISTIR 5690*, National Institute of Standards and Technology, Gaithersburg, July 1995.

5. D.P. Bentz, E.J. Garboczi, and K.A. Snyder, "A hard core/soft shell microstructural model for studying percolation and transport in three-dimensional composite media," *NISTIR 6265*, National Institute of Standards and Technology, Gaithersburg, 1999.

6. K.A. Snyder, "Effect of drying shrinkage cracks and flexural cracks on concrete bulk permeability," *NISTIR 6519*, National Institute of Standards and Technology, May 2000.

7. K.A. Snyder, "Validation and Modification of the 4SIGHT Computer Program," *NISTIR 6747*, National Institute of Standards and Technology, May 2001.

8. K.A. Snyder, "Condition Assessment of Concrete Nuclear Structures Considered for Entombment," *NISTIR 7026*, National Institute of Standards and Technology, July 2003.

9. K.A. Snyder and J.W. Bullard, "Effect of Continued Hydration on the Transport Properties of Cracks Through Portland Cement Pastes in a Saturated Environment: A Microstructural Model Study," *NISTIR 7265*, National Institute of Standards and Technology, August 2005.

10. K.A. Snyder (Editor), C. Langton, B. Clark, C. Ferraris, and J. Dawson, "Engineered Infills for Concrete Barriers," *NISTIR 7311*, National Institute of Standards and Technology, April 2006.

11. K.A. Snyder, D.P. Bentz, J.W. Bullard, C. Ferraris, E.J. Garboczi, N. Martys, P.E. Stutzman, "Measurement Science Needs for the Expanded Use of

Green Concrete," *NIST Technical Note 1783*, National Institute of Standards and Technology, February 2013 (`http://dx.doi.org/10.6028/NIST.TN.1783`).

12. K.A. Snyder and H.S. Lew, "Alkali-Silica Reaction Degradation of Nuclear Power Plant Concrete Structures: A Scoping Study," *NISTIR 7937*, National Institute of Standards and Technology, March 2013.

13. K.A. Snyder and J. Weiss, "Sensors and Monitoring to Assess Grout and Vault Behavior for Performance Assessments," NUREG/CR-7169, Nuclear Regulatory Commission, August 2013.

14. D.P. Bentz, C.F. Ferraris, K.A. Snyder, "Best Practices Guide for High-Volume Fly Ash Concretes: Assuring Properties and Performance," *NIST Technical Note 1812*, National Institute of Standards and Technology, September 2013.

15. K.A. Snyder, L.-P. Sung, and G.S. Cheok, "Nondestructive Testing (NDT) and Sensor Technology for Service Life Modeling of New and Existing Concrete Structures," *NISTIR 7974*, National Institute of Standards and Technology, December 2013.

DISCUSSIONS

1. K.A. Snyder, "Discussion of 'Permeability evaluation of concrete bridge structures exposed to marine environment in Florida' " *Transportation Research Record* No. 1371, 44–45, 1992.

2. K. Snyder, "Discussion of 'A new technique for the measurement of the electric resistivity of concrete,' by V. Lakshminarayanan, P.S. Ramesh, and S.R. Rajagopalan'," *Magazine of Concrete Research*, **45** (162), 75–77, March 1993.

3. K. Natesaiyer, M. Simon, and K. Snyder, "Discussion of 'Mean Spacing of Air Voids in Hardened Concrete,' by E.K. Attiogbe," *ACI Materials Journal*, **91** (1), 123–124, Jan-Feb 1994.

4. K.A. Snyder, "Discussion of 'Influence of measurement technique on the air-void structure of hardened concrete,' by T. Aarre," *ACI Materials Journal* **93**, 512–514, 1996.

5. K.A. Snyder, "Discussion of, 'The use of the flow length concept to assess the efficiency of air entrainment with regards to frost durability: Part I–Description of the test method,' by R. Pleau and M. Pigeon," *Cement, Concrete, and Aggregate* **19**, 116–119, 1997.

6. K.A. Snyder, "Reply to the discussion by C. Shi of the paper, 'Estimating the electrical conductivity of cement paste pore solution from the OH^-, K^+, and Na^+ concentrations' " *Cement and Concrete Research* **35**, 421–422, 2005.