The last 40 to 50 years have seen some marvelous developments in concrete-polymer materials (CPC). Polymer concrete (PC) and polymer-modified concrete (PMC) actually were used in a limited role beginning in the 1950s. With the advent of polymer-impregnated concrete (PIC) in the late 1960s, tremendous interest was focused on CPC. Soon, polymer concrete became the focus of considerable interest for repair of concrete, overlays for floor and bridges, and precast components. American Concrete Institute (ACI) Committee 548 Polymers in Concrete became the fastest growing committee in ACI. Tremendous interest developed internationally and the International Congress on Polymers in Concrete was formed in 1981. Congresses have been held every three years with few exceptions. The amount of research and number of new products have leveled off but today CPC materials are household words in the construction industry.

Are these materials truly sustainable? Indeed they are.

- Polymer concrete permits repairs to be made more quickly than repairs with ordinary concrete. The ability to vary the properties particularly in obtaining lower moduli and higher elongation has resulted in very durable, long-life repair materials. Polymer concrete has proven to be an excellent material for overlaying bridges and floors resulting in greater skid resistance accompanied by fewer accidents and longer life. Precast polymer concrete has also proved sustainable due to the greater durability, longer life, reduced weight and greater strength.
- Polymer-modified concrete has been widely used for making repairs, for spray-on coatings and floor and bridge overlays. The excellent adhesion, resistance to chloride intrusion, and very good durability has made it a very sustainable material.
- Polymers for crack repair have been outstanding. Acrylics and epoxies have changed the way that cracks are repaired and have resulted in much longer life and more waterproof structures.
- Other relatively new applications of polymers include synthetic fibers to provide more resistance to shrinkage cracking in concrete and more ductility. Fiber-
reinforced polymer reinforcement in the form of bars and sheet reinforcement applied externally have changed the landscape of reinforcing concrete.

What does the future hold? The introduction of nanotechnology holds great hope for CPC. Greater strengths, durability and wider uses of these materials are some of the promising developments. Concrete-polymer materials are truly sustainable and will continue to occupy a very important role in our family of specialty materials.

PROF: David W. Fowler, Ph.D., P.E. has many years of experience in teaching, research, and consulting. He holds B.S. and M.S. degrees in ARE from UT and a Ph.D. in CE from the University of Colorado at Boulder. He is the Joe J. King Chair in Engineering and the T. U. Taylor Professor and serves as director of the International Center for Aggregates Research (ICAR) at the University of Texas at Austin where he teaches undergraduate and graduate courses in materials, wood engineering, concrete repair, forensic engineering and design of concrete structures. He has worked for several consultants designing railroad bridges and buildings. He has been the principal investigator on many projects including structural systems and connections for manufactured housing, polymer concrete for repair, developing a precast polymer concrete railroad tie, concrete sealers, concrete crack repair, repair methods for concrete, polymer impregnation for bridge decks, bonded concrete overlays for pavements, micro fines in concrete, aggregate optimization for use in concrete, self-consolidated concrete, and intelligent polymer concrete. Most of his research has been transportation related for the Texas Department of Transportation, the International Center for Aggregates Research, and the Federal Highway Administration. His consulting practice includes forensic investigations related to residential construction, industrial buildings, commercial buildings, pavements, concrete materials, concrete-polymer materials and other structures. He has extensive experience with residential wood construction. He has performed research on manufactured housing floors and walls and on wood connections. His recent research has focused on the use of aggregates in portland cement concrete.

Dr. Fowler has won many teaching awards including the outstanding teacher award in the College of Engineering and the outstanding teaching award for the University. He is a member of the UT Academy of Distinguished Teachers. He has been the recipient of many awards including the American Concrete Institute Delmar Bloem Award and the Robert Philleo Award. He is a Fellow in the American Concrete Institute, the American Society of Civil Engineers, and the Architectural Engineering Institute. He was named an honorary member of the Russian Academy of Engineering in 1992, among the first non-Russians to receive the honor. In 1993 he was named a Distinguished Engineering Alumnus of The University of Colorado at Boulder. In 1995 he received the Owen Nutt Award for distinguished service and leadership in the field of polymers in concrete from the International Congress on Polymers in Concrete. He was named "People In Concrete Repair" by Concrete Repair Digest, 1995, for efforts to improve the concrete repair industry. He was inducted into the National Academy of Engineering in 1998 for his work in the “development and application of concrete-polymer materials.” He received the College of Engineering Joe J. King Distinguished Centennial Award in 2001 and the Billy and Claude R. Hocott Centennial Distinguished Engineering Award, 2002. He is a member of the UT Civil and Architectural Engineering Academy of Distinguished Alumni. In 2005 he was
named a Distinguished Graduate of the College of Engineering at the University of Texas at Austin. In June 2010, he had several sessions named in his honor at the Second International Conference on Sustainable Construction Materials and Technologies in Ancona, Italy. In 2012 the Leadership and Management in Engineering published by the American Society of Civil Engineers named him an Engineering Legend in an article titled: David W. Fowler: World Leader in Concrete Polymer Materials.

He has served on the Board of Directors of the American Concrete Institute and is past chair of the ACI Concrete Research Council, Concrete Research and Education Foundation, and Committee 548 Polymers in Concrete, in which he served as chair, and has served on numerous other committees including 546 Repair and 224 Cracking. He has served on Transportation Research Board Committee A2J03 Mineral Aggregates and chaired TRB A3C14 Polymer Concrete, Adhesives and Sealers. He was the first president of the International Congress on Polymers in Concrete. He has served on the boards of the University Federal Credit Union and the University Co-op. He currently serves as chair of the Men’s Athletics Council at The University of Texas at Austin.

He has served as an expert witness in hundreds of cases, including a number involving polymers in construction, residential construction, concrete materials, stair accidents, commercial structures, concrete pavements, and industrial structures. He has participated in many university courses and short courses involving forensic engineering investigations. He has authored several hundred articles and technical reports. He has given hundreds of lectures in the U.S. and around the world.

**Lecture 2:**

**Polymers in concrete: from an idea into sustainable concrete**

*Prof. Lech Czarnecki, PhD., D.Sc.*

Building Research Institute, ITB Warsaw, Poland
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At the beginning was the fascinating idea: combine the old material which built civilization since centuries with the polymers – the most progressive materials in this time. The place of “polymers in concrete” on a timeline and polymers on the concrete life curve. The aim is always the same: better concrete. Three ways of technological implementation polymer into concrete:

- into fresh concrete mixture (PMC, PCC); polymerisation after mixing (post-mix) or before mixing (pre-mix),
- into hardened concrete (PIC); polymer “forced” under pressure into “concrete”,
- into fresh concrete mixture – without Portland Cement; solely polymer creates a matrix, PC.

Extended contemporary classification of class of polymers in concrete. Long lasting believing that addition of polymers should only improve the concrete; disillusion, verification, optimisation. Material Models of Polymer Cement Concrete – pre-mix (Y. Ohama, M. Puterman, A. Beeldens, D. van Gemert) and post-mix (P. Łukowski);
Searching for synergy. Turning over the “oil peak” has given the new impulse to use polymers - products of oil in more sophisticated way. Nanotechnology as the new wave in material engineering development. Sustainable development and in consequence the sustainable concrete as the civilisation necessity. Since 2012 the sustainable construction works as the fundamental requirement according to the European Regulation. The contribution of C-PC into the prosperity cycle: ideas-innovations-jobs-prosperity. Main driving forces in the C-PC research area. From polymer nanomonitoring into nanomodification. Already exist areas of application where the given type of C-PC is irreplaceable:

- PCC – in typical repairing of the concrete structure;
- PC in the repairs, where quick restoration of usability is required (days or even hours); in the repairs performed under chemical aggression; in the repairs of the concretes of high strength and in every situation where durability in the highly aggressive environment, e.g., electrolytic cells in the copper industry, pipes, other precast elements, including synthetic marble sanitary wares, etc.,
- PIC as the way of preserving the monuments and old buildings. The method is used if other ways cannot be employed and requires the conservation agreement.

In future new technical characteristics will create new applications (D.Fowler). Future Concrete Polymer Composites should materialise the main contemporary ideas: sustainable development in civilisation and nano-approach in technology.

Porf Lech Czarnecki PhD, D.Sc. – is the Scientific Secretary of Building Research Institute and Professor at Warsaw University of Technology. He was the President of International Congress on Polymers in Concrete, ICPIC (2006 – 2013), formerly he was the Vice-president of ICPIC from 2001 to 2006. Also he is the member of Board of Directors since 1992 until now. He is senior member of International Union of Testing and Research Laboratories for Materials and Structures, RILEM since 1992. He is the consultant member of American Concrete Institute, ACI Committee 548 since 1989. Professor is also the Polish delegate of European Cooperation of Science and Technology, COST – Transport, Urban Domain since 2006. From 1972 to 2011 he was the Head of the Building Materials Engineering Department of Warsaw University of Technology and Vice–Rector for Academic Affairs (2000 –2006). He has been for 10 years the Scientific Director of the Institute of Technology and Organization of Building Production at Warsaw University of Technology. What is more, he was the member of the Senate of the University and the Chairman of the Committees of the Senate for the Academic Ethics and for the International Cooperation (1993-2006). Lech Czarnecki was awarded “for eminent activities in new frontiers of building materials engineering” by the Society of Materials Engineering for Resources in 2009 and “for distinguished service and leadership in the field of polymers in concrete” Owen Nutt Award in 2004. Since 1993 to present he is the member of the Committee of the Civil Engineering of Polish Academy of Sciences. Since 1994 until now he is the member of Technical Committees for Polish Standardization. His research topics concern building material engineering, concrete technology, polymers in concrete, nanotechnology and sustainable development.

Professor Czarnecki was the leader of several national and international scientific projects, among others, “Concrete-Polymer Composites” – joint program with the NIST, USA, and “Polymer Composites for Repairing of Portland Cement Concrete: a Compatibility Project” under the same Joint Fund, as well as, “Ultrasonic Evaluation Methods Applicable to Polymer Concrete Composites” also conducted in his scientific team at Warsaw University of Technology in co-operation with the NIST.

He has presented invited lectures on Concrete – Polymer Composites at Technical University in Aachen, Germany; Technical University in Prague, Czechoslovakia; Free University in Brussels, Belgium;
Chalmers University in Göteborg, Sweden, as well as at Universities in: Barcelona, Spain; Haifa, Israel; Zagreb, Croatia; Nihon University in Koriyama and Akita University, Japan; University of Tennessee at Knoxville, University of Texas at Austin and University of Michigan at Ann Arbor in USA, moreover, in EMPA Central Laboratory, Switzerland; Brookhaven National Laboratory, Long Island, N.Y.; National Institute of Standards and Technology, Gaithersburg, USA, Mitsui Petrochemical Industry in Japan and ICPIC – Japan Chapter also in Japan.

He is author or co-author of more than two hundred scientific (Hirsch index according to the Publish or Perish, $h=16$) and technical papers (more than hundred in English) as well as many research project reports and 38 patents (one of them has been patented in ten countries). He has served as the General Reporter on the RILEM International Symposia (Prague 1981, Liege 1984, Aix-en-Provence 1986, Bochum 1990) and ICPIC Congresses (Bologna 1998, Hawaii 2001, Berlin 2004, Chuncheon 2007, Istanbul 2012, Shanghai, 2013). Recently, he presented *Tendencies Shaping the Future of Building Materials* as the keynote speaker on the European Strategic Workshop: *Shaping Cities for New Challenges*.