

History of Construction, Engineering, and Management in the Department of Civil and Environmental Engineering at Penn State

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Abstract: At Penn State, the credit for broadening the Civil Engineering Department's longstanding academic focus on analysis and design to include the construction phase must go to Dr. Harmer A. Weeden and his longtime associate Dr. Thomas D. Larson. Jack H. Willenbrock joined the Department as an Instructor in June 1968 and grew the construction program so that today about a fourth to a third of the civil undergraduates obtain employment in the construction industry. The program has awarded about 250 postbaccalaureate degrees.

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Early Years

A recognition of the need to include a focus on the construction phase of projects in the education of both undergraduate and graduate students began to develop in civil engineering programs at a number of universities in the United States in the late 1950s and early 1960s. Perhaps a partial impetus for that was the passage of the Federal Aid Highway Act of 1956 which established the grand plan for the design and construction of the Interstate System of Highways and provided increased opportunities for employment of civil engineering graduates throughout the United States.

At Penn State, the credit for broadening the Department's longstanding academic focus on analysis and design to include the construction phase must go to Dr. Harmer A. Weeden and his longtime associate and friend, Dr. Thomas D. Larson. Weeden, who received his degrees from Cornell University, pursued a primary teaching and research focus throughout his career in the area of Surveying, but also understood how important the construction phase was to the successful completion of engineering projects. Larson, who received his degrees from Penn State, completed his Ph.D. in 1962 in the area of construction materials under Professor Gib Reen. He had a natural interest in the methods and equipment used during the construction phase because of earlier work assignments with the United States Navy, a

coal company, and H. R. Imbt Services, Inc., a highway and heavy construction firm located in State College, Pa. Additionally, Larson's postdoctoral studies at Oklahoma State University exposed him to the work of Professor R. L. Peurifoy (one of the leading pioneers in establishing an academic focus on construction management).

Larson and Weeden established two courses between 1962 and 1966 which focused on the construction of engineering projects. The undergraduate course, C.E. 431, dealt with the planning, methods, and equipment involved during the construction phase. The graduate course, C.E. 550, emphasized the field and corporate management of highway and heavy construction projects.

The expansion of interstate highway construction in Pennsylvania during the 1960s led to establishing strong and active contacts with Herbert R. Imbt and the Associated Pennsylvania Constructors (APC), a highway-oriented trade association located in Harrisburg, Pa., in which Mr. Imbt served as an officer. The first Master of Science Degree in the construction area was in fact awarded in June 1966 to Roger F. Herzog, a civil engineer employed by H. R. Imbt Services, Inc. His thesis dealt with the application of the critical path method to medium sized highway construction projects.

By late 1967, it became apparent that Larson's increased responsibility in establishing and serving as the first director of the Pennsylvania Transportation Institute (PTI), and Weeden's desire to concentrate fully on the surveying and photogrammetry areas required someone with experience in construction management to guide the further expansion of this academic area. Joint meetings between Larson, Weeden, leaders of APC and Dr. Benjamin Whisler, the C.E. Department Head, resulted in Whisler authorizing a search for a candidate for an Instructor position in the spring of 1968. An incentive for Whisler was that APC agreed to provide the support for the majority of the salary of the Instructor position until the individual obtained his/her Ph.D.

Jack H. Willenbrock (Fig. 1) joined the department as an Instructor in June 1968 after receiving his first two degrees from The Cooper Union and Lehigh University and managing chemical plant and laboratory construction projects for 6 years for the E.I. DuPont de Nemours Company in New Jersey. His doctoral stud-

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Fig. 1. Jack H. Willenbrock, Ph.D., P.E.

ies, under the supervision of Weeden and Larson, focused on operations research, management, and statistics and culminated in March 1972 in a dissertation which compared expected monetary value and expected utility value bidding strategy models for highway contractors.

During the period from 1968 to 1972 Willenbrock taught a number of introductory courses in the department and assumed responsibility for the two existing construction courses. He also created a “trust relationship” with APC and other highway construction associations in Pennsylvania by establishing a continuing education program in which he developed, directed, and taught in 17 seminars and workshops which were attended by over 500 industry personnel.

Expansion Initiatives: 1972–1980

Willenbrock, as the leader of the construction, engineering, and management (CEM) area after 1972, began a series of expansion initiatives over the next 8 years. Active committee participation in the Construction division of The American Society of Civil Engineers (ASCE), as well as the Transportation Research Board (TRB) and the American Road and Transportation Builders Association (ARTBA), and charter membership for Penn State on ASCE’s Construction Research Council (CRC) in 1976 helped to establish a national reputation for the CEM program. Several new courses, including a 400 level course in Construction Project Control, in 1973, and two 500 level courses in Legal Aspects of Construction in 1975 and Power Plant Construction in 1977 were developed and introduced by him.

Prior to 1980 the graduate student enrollment in the program was primarily focused on the MS/MEngr. level. Only three masters level degrees were awarded prior to 1972. Growth occurred during the period from 1972 to 1980: a total of 28 master’s level

degrees were awarded as construction industry interest and sponsored graduate work-study fellowship and research support developed. A “Service before Funded Research” model was adopted (with service consisting of technology transfer/continuing education programs for the construction industry) in order to create future research funding opportunities. Documentation of the completed research reports was started in 1972 with the establishment of a CEM Research Series.

A focus on statistical quality control (SQC) was started in 1973 when APC requested an SQC workshop in response to the development and implementation of SQC specifications by the Pennsylvania Department of Transportation (PennDOT). The workshop, presented by Willenbrock, led to successive research/technology transfer contracts with Penn DOT, the Federal Highway Administration (FHWA), and in the late 1970s, with the Federal Aviation Administration (FAA). These contracts developed customized SQC training manuals for each sponsor and ultimately a total of 16 1-week-long workshops were presented for approximately 600 industry personnel. As a result of the expertise developed, two applied research contracts related to “adjusted price systems” and “acceptance plan development” were obtained from Penn DOT and FAA, respectively. In addition, contact with FAA led to the development and presentation of the first Airport Engineering Conference at Penn State in 1979—the beginning of a series which Willenbrock directed until 1987 and which has continued with Penn State sponsorship for over 25 years. In 1988, Willenbrock received a “Certificate of Appreciation” award from FAA for that series. A number of students received financial support for their graduate work as a result of the SQC initiative. In addition, the knowledge of the construction industry which was acquired resulted in a number of modifications to the existing undergraduate courses.

As a result of the above-noted expansion initiatives, and several others that were on the horizon, two new CEM faculty were added to the C.E. Department in 1975. The first, Dr. H. Randolph Thomas, Jr. (Fig. 2) had a background in structures, having received his doctorate from Vanderbilt University with a research focus in structural optimization. By 1978 Thomas was totally committed to the CEM area, although he initially continued his research interest in structures and taught both structures and CEM courses. Willenbrock and Thomas essentially shared the leadership of the CEM area for the next 17 years.

James L. Burati, Jr. (Fig. 3) started as an Instructor in the fall of 1975 after completing a construction focused M.S. degree at Ohio State University. Over the next 5 years he taught undergraduate courses in the CE Department, assisted in the development and presentation of technology transfer/continuing education courses in both the SQC and power plant construction areas, and performed research related to the quality assurance of construction materials. This research focus culminated in the development of the first statistically based bituminous pavement specification adopted by the Eastern Region of FAA, and receipt of his Ph.D. Burati left Penn State in 1980 to assume a faculty position at Clemson University, where he currently holds the rank of Professor of Civil Engineering.

This expansion of faculty allowed the responsibilities related to undergraduate and graduate teaching and advising to be distributed, the SQC initiative to be expanded and more effectively managed, and an expansion initiative into industrial construction (targeted on the power plant sector of the construction industry). A closer association was also established with the emerging CEM graduate program in Penn State’s Department of Architectural Engineering.

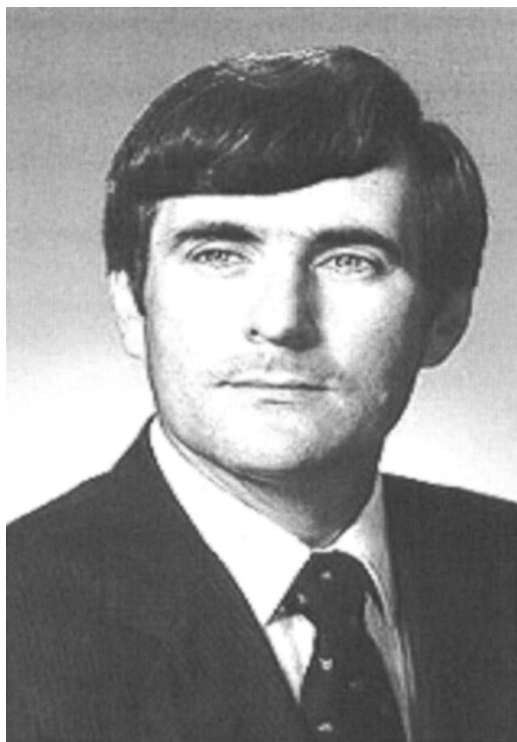


Fig. 2. H. Randolph Thomas Jr., Ph.D., P.E.

The 1970s were the heyday for nuclear power plant construction projects in the United States. In response to the high level of activity in this sector in Pennsylvania and surrounding states, a "Power Plant Construction Advisory Group to Penn State" was established by Willenbrock and Thomas in December 1975. Its purpose was to guide the undergraduate, graduate, and continuing education efforts of the Department in the power plant construction area. With the assistance of the group, Willenbrock and Thomas were able to obtain a research/technology transfer contract from the federal government in 1976. It covered the preparation of educational materials and provided scholarship support for over 40 CEM faculty from universities throughout the United States which allowed them to attend a 2 week conference at Penn State to learn about this area of emerging knowledge. Thirty industry participants also attended the conference. A follow up 1 week conference for 50 industry participants was held in 1978. The initial "Service" initiative eventually resulted in a large research contract from the federal government which allowed Willenbrock, Thomas, and Burati to study the structural concrete quality assurance systems on nine nuclear and three fossil-fueled power plant construction projects. In addition it provided Thomas with a research contract in 1978 to study the implementation of a cost/construction methods improvement program on a specific nuclear power plant construction project. This power plant construction initiative culminated in 1980 when Willenbrock and Thomas served as coeditors on a John Wiley textbook entitled: *Planning, Engineering, and Construction of Electric Generation Facilities*, which documented the existing body of knowledge about the construction of power plants. They also planned and directed an ASCE National Specialty Conference related to power plant construction in 1981, the proceedings of which were published by ASCE in 1982. In addition, Willenbrock was able to study nuclear power plant construction practices in Germany while serving as a Visiting Professor at the



Fig. 3. James L. Burati Jr., Ph.D.

Technische Universitat in Munich, Germany during the summer of 1980.

Period of Transition: 1981–1985

A number of transitions occurred in the CEM area during this period. Thomas guided the development and introduction of a 300 level course entitled Engineering and Construction Practice in 1981, which served as a prerequisite for the 400 level courses. In addition, the expansion initiatives, begun during the 1970s, attracted a large number of graduate students to the program, resulting in 53 Master's level degrees being awarded between 1981 and 1985. Active interaction with the United States Army, Navy, and Air Force, begun in 1980, resulted in a large contingent of these CEM students having a military background. Burati became one of the first two Ph.D. graduates of the CEM program in May 1984 after he completed his SQC-oriented dissertation entitled: "A Bayesian Acceptance Approach for Bituminous Paving Materials." At the same graduation commencement, Felix T. Uhlik, an officer in the U.S. Air Force, received his Ph.D. from the CEM program after having completed an operations research-oriented dissertation. His first academic appointment was at the Air Force Academy.

Strong relationships and a research presence had been developed by Willenbrock and Thomas with both the: (1) highway/airport/heavy and (2) power plant sectors of the construction industry due to their work in the 1970s. As an example, in 1984 Willenbrock was a corecipient of the prestigious K. B. Woods Award for the best technical paper in the area of design and construction of transportation facilities at the annual meeting of the TRB. Two events, which were totally out of their direct control, occurred in 1979/1980 that caused a change of focus during the

1981 and 1985 time period. The first occurred in the aftermath of the nuclear accident involving the Unit 2 Reactor at Three Mile Island near Harrisburg, Pa. in March 1979. The years immediately after the accident caused a contraction in the industry and a loss of industry funding support for additional technology transfer/research projects. The second occurred in December, 1979 when alumnus Bernard Hankin, a successful land developer and home builder from Exton, Pa., challenged Penn State to create a program in the College of Engineering which would help professionalize the residential building construction industry. He backed up his challenge by providing the funds necessary to establish the Bernard Hankin Professorship of Residential Building Construction in February 1980.

Willenbrock and Thomas continued to work together under the broad CEM framework well into the late 1980s. However, the events described above, and the desire of each to achieve a depth of expertise in specific focus areas, necessitated that some important transitions occur between 1981 and 1985. For instance, a division of responsibility for the courses taught in the CEM program was established. A one credit Construction Seminar, which introduced construction research methodology, was also introduced in the fall of 1982 in order to more effectively manage the large number of graduate students in the program. Students were expected to have selected their individual research topics by the end of that course or their first semester in the CEM program.

Thomas's major transition during this period included accepting the responsibility for the still evolving "Legal aspects of construction" course and enhancing its focus on contract interpretation and contract administration. In addition he initiated a graduate course in "Productivity measurements, analysis and control." This package of two courses gave the CEM graduate students an increased understanding about site management operations and processes. It was also decided that Thomas would gradually assume more responsibility as the leader of the CEM area if Willenbrock's involvement with the new residential construction program evolved as expected.

In order to pursue his research interests, Thomas became one of the key faculty members associated with the Pennsylvania Transportation Institute (PTI) at Penn State, and eventually headed up PTI's Construction Engineering and Management program. During this time period some significant construction automation research took place there under his direction. Researchers developed ways to identify construction equipment and determine if it was loaded or empty using acoustical signal processing. They also developed an automated method for estimating the bearing capacity of driven piles using seismic wave analysis and developed an automated real-time density measurement device for asphalt pavement. This innovation ultimately resulted in the award of a United States patent. The application of GPS devices to construction processes was also tested. Thomas also broadened his research base beyond highway/heavy construction by beginning a focus on the construction of industrial and commercial projects.

Willenbrock's major transition into almost a full-time focus on the residential construction industry in the late 1980s actually began in February 1980 when he accompanied the heads of the C.E. and A.E. Departments on their initial visit to Bernard Hankin's office in Exton, Pa. Throughout the following few months, he provided advice to them about how Penn State could respond to the opportunity that had been created. In July 1980 he was asked to serve as the faculty member in charge of the residential construction initiative for the 1980–1981 academic year. The initial development phase culminated in August 1984 when he was selected as the first Bernard Hankin Professor of Residen-

tial Building Construction. By the end of 1985 the following components of the program were operational:

1. Residential Courses—one of the first components put in place, in close cooperation with industry leaders, were two 400-level courses for C.E. and A.E. students:
 - Residential Subdivision Design and Construction; and
 - Residential Building Design and Construction.
 Both of these courses culminated in group developed "capstone design projects."
2. NAHB Student Chapter—with the assistance of J. Roger Glunt, a home builder from the Pittsburgh area and the Pennsylvania Builder's Association (PBA), Penn State received its charter for a student chapter of the National Association of Home Builders (NAHB) in December 1980. Members of the chapter are selected annually to receive scholarship support from residential construction associations and firms as an encouragement to pursue careers in the industry.
3. Technology Transfer-Continuing Education—Willenbrock spent considerable time between 1980 and 1985 establishing "trust relationships" with the industry in Pennsylvania as a first step in applying the "Service before Funded Research" model to the residential building construction industry. This effort culminated in the fall of 1984 when he requested that PBA establish a permanent Education and Training Committee. It met for the first time in April 1985 at Penn State. A PSU/PBA/NAHB educational partnership was established and it adopted the Graduate Builder Institute (GBI) program as the basic format for technology courses that would be offered to the residential construction industry in Pennsylvania. The first GBI courses were offered in November 1985 and the series continued for the next 10 years. This established broad exposure for the program and placed Pennsylvania in a leadership role in the United States for this level of educational commitment to residential builders.
4. Graduate Student Research—as interest in the program increased among CEM graduate students, funds for several small research projects were obtained. The first Master's level degree in the program was awarded to Dennis Biddick, a Naval officer, in 1983. Biddick examined issues related to factory built housing. By the end of 1985 a total of five Masters level degrees had already been awarded in the program. Documentation of the completed research reports was started in 1985 with the establishment of a Residential and Light Building Construction Research Series.

It should be noted that Willenbrock and Thomas were the only faculty members in the CEM area during the first half of the 1980s. Dr. Jose Guevara joined the CEM faculty as an Assistant Professor in 1985; he assisted teaching the undergraduate CEM courses but left after 2 years. As a result of this lack of critical mass, three "Special Projects" 500 level courses developed by Willenbrock in the period from 1980 to 1983 (Construction Safety Management and Control, Labor Aspects of the Construction Process, and Statistical Quality Control of Construction Materials) were never transitioned into permanent courses. In addition, the 500 level Power Plant Construction course was taught for the last time in 1984.

CEM Program: 1986–1995

Thomas began an intensive study of construction processes during this period, a focus which would establish the signature research character of his contribution to the CEM program.

Research was conducted into productivity measurements, the effect of scheduled overtime, and the effects of change orders. Thomas also began a program of collecting labor productivity data on commercial projects. All data were collected according to a *Procedures Manual* which he developed so that data from multiple projects could be combined and analyzed. In conjunction with this effort he began collaborating on a regular basis with researchers in Eastern and Western Europe and South America on issues related to labor productivity. This was the beginning of long-lasting friendships which has allowed Thomas to travel to many corners of the globe to observe construction operations. As of 2005, the data base contained about 175 projects covering more than 5,000 work days and approximately 300,000 work hours. About 40 of these are international projects.

In the legal area Thomas pioneered the development of new, more reliable ways to quantify losses of labor productivity on complex, disputed projects. His work has been published in construction law journals. Because of his research and growing reputation, he has been retained as an expert witness on a number of high profile construction dispute cases since the mid 1980s. He also has developed a comprehensive legal workshop manual and has presented almost 20 workshops dealing with construction contract interpretation across the United States since the mid 1980s.

Willenbrock continued to teach several general CEM courses each year until 1995 and 60% of the 25 Master's level students he directed between 1986 and 1991 were general CEM graduate students. One of his initiatives resulted in the sponsorship of fully funded graduate scholarships by the Shimizu Construction Company (one of the "Big Five" construction firms in Japan) for seven of its construction engineers between 1984 and 1993. A sponsored trip by the firm to Japan in 1986, for a speaking engagement at an international construction symposium and a visit to the firm, prepared Willenbrock to more effectively direct the master's level graduate programs of these students.

It became evident that Willenbrock would be pulled more into the residential construction sector in the late 1980s, so another CEM faculty member was needed. As a result, Dr. Gary R. Smith (Fig. 4), who had received his Ph.D. from Purdue University in 1986, was hired as an Assistant Professor of civil engineering and a member of the CEM group that same year. His dissertation was an extension to critical path scheduling theory using fuzzy algorithms to simulate weather impacts to the schedule duration. Professionally he had worked in consulting as a structural design engineer, surveyor, and as a construction engineer prior to his graduate work at Purdue. While at Penn State he taught the construction equipment and methods and the estimating and scheduling courses, and cotaught the residential subdivision design and construction course in the residential construction area. His research included an early study of plant efficiencies for a modular home manufacturer, a "Research Implementation in Construction" project sponsored by the Construction Industry Institute, and a "Contractor Qualifications" project sponsored by the National Cooperative Highway Program. He was also active in teaching continuing education and extension courses in the areas of construction safety and contract interpretation. Smith left Penn State in 1997 for Iowa State University's Construction Engineering program where he taught until 2000. He then assumed the Director and eventually Chair position in the Department of Construction Management and Engineering at North Dakota State University. In June 2005, he became Dean of the College of Engineering and Architecture at North Dakota State University.



Fig. 4. Gary R. Smith, Ph.D., P.E.

Residential Construction Program: 1986–1995

The basic foundation components of the program which were in place in 1985: two residential courses, an NAHB Student Chapter and a strong partnership with PBA at the state level (partly because of the GBI series of technology transfer courses), were incrementally improved but not greatly altered over the next 10 years. One of the key improvements for the undergraduate teaching component which should be noted is the gradual development of a fully operational "Residential Construction/Surveying CADD Laboratory," which greatly improved the professionalism of the capstone design projects in both courses. Initial funding for the first version of the lab was provided by Bernard Hankin. A review of the program and industry guidance regarding needed improvements was provided through annual meetings of the "Bernard Hankin Professorship Advisory Committee." The two major components added during this period were: (1) the establishment of a national leadership role for the program and (2) the introduction of a strong sponsored research (both applied and theoretical) component into the program. It is interesting to note that neither of these were a part of Bernard Hankin's original vision when he approached Penn State with his "Dream" in 1979.

Willenbrock returned from his first NAHB Annual Meeting in January 1984 with the distinct impression that very little industry/academic interaction existed at the national level. As an initial step toward remedying that situation; PBA, Bernard Hankin, and J. Roger Glunt supported the appointment of Willenbrock to the Board of Directors of the NAHB Research Center in March 1985. This prestigious appointment provided national exposure for the Penn State program and opened up communications with both the industry and academic research communities. Willenbrock continued, as the only academic member of that board, for the next 10 years. Using this position, Willenbrock was able to work with the leadership and staff of the NAHB Research Center, and several other faculty members from research oriented universities, from 1986 to 1988, to create the conceptual framework and original operating policies for a network of NAHB Research Center Des-

ignated Housing Research Centers. In July 1988, after an extensive proposal review process, the original network consisting of the NAHB Research Center, Penn State, and 12 other research oriented universities was announced. For the last 18 years this network, which currently includes two more universities and is known as the National Consortium of Housing Research Centers, has played an important role at the national level as a forum for: research information exchange, addressing current research and development needs, developing innovation solutions, and shortening the time of adoption of these innovations by segments of the home building industry. Willenbrock served as the Chairman of the Board of Directors of the Consortium from 1990 to 1992.

As the Hankin Professor, Willenbrock was also appointed as the first Director of the designated Housing Research Center (HRC) at Penn State in 1988 and led it through its first 7 formative years. In that capacity, he was the primary representative and contact of the HRC with the residential construction industry at the state and national level. He was also responsible for directing the strategic planning process, identifying new research and technology transfer opportunities, and assembling the internal faculty resources at Penn State into research teams who could respond to the opportunities and for the administration and management of current projects. From 1988 forward the HRC became the research and technology transfer component of Penn State's overall commitment to the residential construction industry in Pennsylvania. An Assistant Director of Operations position was created and was filled, by design, with a succession of Ph.D. level graduate students who showed promise as either future university faculty or as industry researchers associated with the home building industry. During this period, the position was ably filled by Madan G. Syal, Steven B. Taylor, Stacey K. Worley, and Charles McIntyre, who each focused their doctoral dissertation work on research projects funded by the HRC (both Syal and McIntyre currently hold senior faculty positions in programs at Michigan State University and North Dakota State University, respectively, where they are teaching the next generation of home builders). An Advisory Council, consisting of representatives of PBA and other key segments of the residential construction industry in Pennsylvania as well as a number of Penn State faculty researchers met for the first of their annual meetings in June 1989. One of the primary functions of the Advisory Council was to establish the desired research/technology transfer project agenda each year and then to designate a level of funding for each project based upon the total funds raised by PBA and other sources for that year. By the end of 1995 the major emphasis areas of the HRC at Penn State were: energy analysis and optimization, characterization, testing and modeling of structural and building material systems, computerized applications in the home building industry, construction management, subdivision infrastructure systems, and technology transfer.

In the spring of 1988 the College of Engineering provided a grant of \$3,000 to support the initial fund raising effort on behalf of the HRC. The seed money was transformed into a total level of research support of almost \$1.2 million by August 1995. Approximately 38% (\$444,000.00) was raised in the form of either proprietary research support or grants to support nonproprietary research from an industry in Pennsylvania which basically consists of many small entrepreneurs who, on average, each build less than ten houses per year. It is an industry which, prior to the creation of the HRC at Penn State, did not have a program in place for supporting either research and development or technology transfer. The success of this fund raising effort was built upon the development of a trust relationship between the academic and

industry partners involved in this endeavor. Approximately 40% (\$467,000.00) was provided to the HRC at Penn State in the form of matching grants from the Ben Franklin Partnership, an economic development program under the auspices of the Department of Commerce in Pennsylvania. Between 1989 and 1991 the total state funding was shared with Carnegie Mellon University and the University of Pennsylvania who, along with the HRC at Penn State, were joint partners of the Pennsylvania Advanced Technology Housing Consortium (PATHC). Matching state funding from 1992 to 1995 was provided directly to the HRC at Penn State by the Ben Franklin Technology Center of Central and Northern Pennsylvania after PATHC was dissolved in December 1991. As a direct result of this industry/university partnership, a stream of research project support from the federal government began in 1992 and had reached \$225,000.00 (22% of the total) by the end of 1995.

Prior to the start of the HRC in 1988 the research projects related to residential construction were limited in scope and supported, whenever possible, by funds generated through the Hankin Professorship Endowment. Even with this low level of funding, the completed thesis/engineering reports of 14 Master's level graduate students were included in the Residential and Light Building Construction Research Series between October 1983 and May 1989. The first report in the successor HRC Research Series was completed in July 1990 by Dr. Gary R. Smith and documented a proprietary "Modular Home Production Study" funded by Roger Lyons of Penn Lyon Homes, Inc. During the period which ended in 1995, a total of 42 proprietary and nonproprietary reports were issued in the HRC research series. It is important to note that an additional 11 Master's level and four Ph.D. level graduate students were able to fund their dissertation work because of the HRC program. A total of nine Penn State faculty members which included professors: Gary R. Smith, David A. Long, and Gert Aron, of the Dept. of Civil Engineering; Thomas B. Brown, Francois Grobler, Gren Yuill, and M. Kevin Parfitt of the Dept. of Architectural Engineering; and Phyllis F. Adams and Harvey B. Manbeck of the Dept. of Agricultural and Biological Engineering were the closely affiliated faculty who served as principal investigators on these projects and, in some cases, also served on the Advisory Council of the HRC. Manbeck, who was a key faculty member committed to the goals of the HRC, also served as the Interim Director of the HRC in the last half of 1995.

One of the most important roles of the HRC was the dissemination of the results of the research. In addition to the above mentioned HRC research series, dissemination was accomplished through innumerable, oral presentations at industry meetings such as the annual conventions of both PBA and NAHB; HRC sponsored short courses, seminars, and training workshops; technical papers published in referred journals and articles in trade publications; as well as summarized HRC newsletters, fact sheets, and builder-technical-research briefs. In addition, one of the early visions of the HRC was the sponsorship of a series of annual Pennsylvania housing conferences which would bring together all of the diverse stake holders in the housing industry of Pennsylvania under the neutral academic umbrella of Penn State's HRC. The predecessor of this series, which was held in April 1989 and was entitled: "Modular housing: The trend of the 90s," was attended by 175 people. In February 2006, the 14th Annual Pennsylvania Housing Conference was held in both Pittsburgh and Valley Forge and the 2nd Annual Pennsylvania Land Development Conference was held in Valley Forge. A total of 360 people attended these presentations in 2006.

Several other important milestones for the residential building

construction program which occurred during this period should be noted. In 1986 the Bernard Hankin CEM Research Laboratory was established and dedicated in the Sackett Building. This was followed in 1988 by the establishment of an interim HRC location, also in the Sackett Building, which provided office space for the Director and the HRC graduate student staff. In 1987 the NAHB/Home Builder Institute (HBI), presented Willenbrock with their "Outstanding University Associate Award" for his pioneering leadership in promoting the GBI program. In 1989, in response to the favorable progress which had been made at Penn State, the Hankin family increased their endowment to \$1 million and established the Bernard and Henrietta Chair in Residential Building Construction. Willenbrock became the first holder of that Chair in August 1990. He was able to obtain a broad perspective about the key national level issues facing the residential construction industry during a sabbatical year from August 1992 to June 1993 when he served as the first "Scholar in Residence" at NAHB and the NAHB Research Center in Washington, D.C. While there, he organized and participated in a "Presidential Tour" with J. Roger Glunt, the 1993 President of NAHB, of 11 colleges and universities throughout the United States which had a residential focus. In addition, he was appointed to the team which developed the total quality management (TQM) program for the NAHB Research Center. During the prototype stage he applied that program to a large home building firm in Pennsylvania and also served on the first jury which selected home building firms for the National Housing Quality (NHQ) Awards. During the years since then, he has been instrumental in the evolution of that quality program to its present state. In 1993 Willenbrock was awarded the prestigious Whirlpool/HBI Outstanding Educator Award for his leadership role in the industry. In January 1994, J. Roger Glunt established a \$60,000.00 endowment which sponsored the J. Roger Glunt graduate level fellowship in residential construction at Penn State. Brennan Glantz, a graduate student researcher, was selected as the first recipient of that fellowship in 1995.

Jack Willenbrock retired from Penn State with Professor Emeritus status in August 1995 to become the President of JHW: C/M Consultants. Dr. Harvey Manbeck graciously agreed to be the interim director of the HRC until January 1, 1996 when Dr. Eric Burnett became Willenbrock's successor. Willenbrock wrote two books during his consulting period which documented some of the key aspects of the residential construction program at Penn State. The first, entitled: *Residential Building Design and Construction*, was coauthored by Harvey B. Manbeck and Michael G. Suchar (a Master's level graduate of the program). It was published by Prentice-Hall, Inc. in 1998 and reflects the organization of the course by the same name in the program. The book is currently being used at Penn State as well as by a number of other universities in the United States. The second book, entitled: *Benchmark Your Business: Guidelines for Success*, was published by NAHB's Builder Books in 2004. Its framework is Penn State's "Leadership/Management Growth Model" originally developed by Walter A. Music and Hector A. Dasso, two of the early Master's level graduate students in the program in the mid 1980s.

Willenbrock was also invited to serve as a visiting Eminent Scholar at the Del E. Webb School of Construction at Arizona State University for the summer session in 2001. In that capacity, he taught a graduate-level course entitled "Organizational Change and Quality Improvement in the Home Building Industry." He also presented a workshop entitled "Management Guidelines for Growth-Oriented Home Builders" for the Alliance for Construction Excellence. The topics covered in both the graduate course



Fig. 5. Sunil Sinha, Ph.D.

and the workshop were closely associated with the second book noted above.

CEM Program: 1995–Present

In the mid 1990s the CEM faculty began to receive outside recognition for their long and continued contribution to research and education. In 1995, for example, Willenbrock was awarded the prestigious Pourifoy Construction Research Award given by ASCE for his contributions to construction engineering and the construction industry through education and research in the heavy and highway, power plant, and residential sectors. Thomas also received the Pourifoy Construction Research Award given by ASCE in 2001 for his meritorious research in the area of labor productivity. In 1997, Thomas was a visiting scholar at the University of Sao Paulo, Sao Paulo, Brazil. In 1998, Thomas became the first Fulbright Scholar from the Civil and Environmental Engineering Department. He spent 5 months studying labor productivity in Eastern Europe.

In 2001, Dr. Sunil Sinha (Fig. 5) joined Thomas in the CEM area. He had received his Ph.D. degree in Civil Engineering from the University of Waterloo, Canada. His research area is underground infrastructure (pipelines). His Ph.D. research involved vision systems for automated inspection and characterization of pipe damage. During his brief tenure at Penn State he has received a prestigious career award from the National Science Foundation and has conducted research into underground infrastructure for a number of state DOTs. As a result, the scope of CEM research continues to broaden and now includes pipelines. Thomas, in collaboration with others at the University of Florida, has developed processes that will improve time performance on highway projects. Additionally, several benchmarking studies

were completed, one which benchmarked international labor productivity and two others which benchmarked union interior system contractors. It has been recognized by Thomas that CEM, as a discipline, still lacks the fundamental principles of site construction management. Recent research has sought to alleviate this void. To date, fundamental principles have been developed to mitigate the negative effects of adverse weather and congested work areas, material management, sequencing, and planning.

Overall, despite being the most recently developed program in the CEE Department, the CEM program has blended quite well into the mission of the department. Today about one-fourth to one-third of the CEE undergraduates obtain employment in the construction industry in some capacity. The CEM program has maintained at least one active research project for the last 30 years (usually more), has awarded about 250 postbaccalaureate degrees, and teaches 40% of the graduating seniors about construction practices.