Reflections on the Early Precast/Prestressed Concrete Industry in America

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This article traces the evolution of the precast/prestressed concrete industry in the United States from the Walnut Lane Bridge to the present. The beginnings of the industry are described in Florida and other states together with the formation of the Prestressed Concrete Institute. Emphasis is placed on the role the early pioneers played, the products they developed, and the events that shaped the industry. In particular, the development of seven-wire strand, the double tee, hollow-core slab, I-beam, bulb-tee girder and other products are discussed. Early PCI efforts at writing a building code and the struggle to get provisions on prestressed concrete incorporated into the ACI Code are also discussed. The article concludes by emphasizing the need for much greater partnering design efforts in order to move the industry forward into this century.

Norman L. Scott is founder and director of The Consulting Engineers Group, Inc., a design firm he established in 1966, and whose sole objective is to service the precast/prestressed concrete industry. After obtaining his BS degree in civil engineering from the University of Nebraska, Norm Scott joined R. H. Wright & Son, Inc., in Fort Lauderdale, Florida. In 1959, he was appointed PCI's second executive secretary and moved the PCI Headquarters from Boca Raton to Chicago. Over the next 45 years, he played a major role in the growth and success of the precast/prestressed concrete industry. In recognition of his important contributions to the industry and Institute, he has been honored with PCI's two highest awards – the Medal of Honor and Fellow.

I was born in the little town of Meadow Grove near Norfolk, Nebraska. Upon high school graduation in 1949, I applied and was accepted in the College of Engineering at the University of Nebraska in Lincoln (the home of the famous Cornhuskers football team).

The year 1949 was a very auspicious year because it was the start of construction of the Walnut Lane Bridge in Philadelphia, Pennsylvania – the first major prestressed concrete structure in North America. At the time, of course, as a neophyte student, I was unaware of the significance of this event nor of the impact it would have in igniting the beginnings of a new industry and influencing my life and professional career.

Since my interests were in structures, I enrolled in the Department of Civil Engineering. At that time, there were no courses in prestressed concrete. (Indeed, even today, most universities do not offer courses in prestressed concrete except at the graduate level.) I took two courses in concrete – conventionally reinforced concrete as a design component and

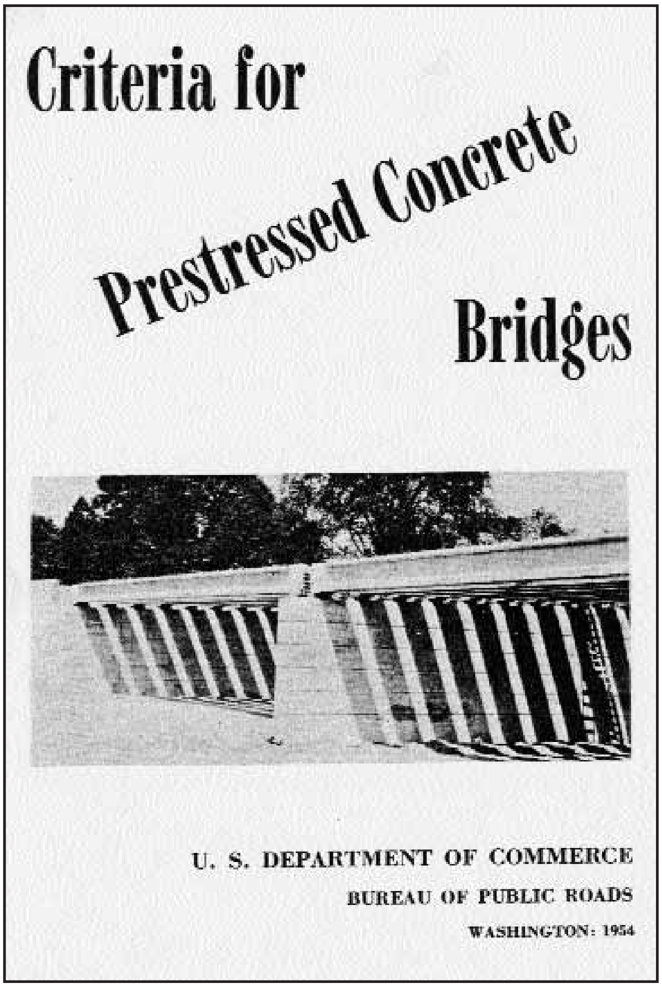
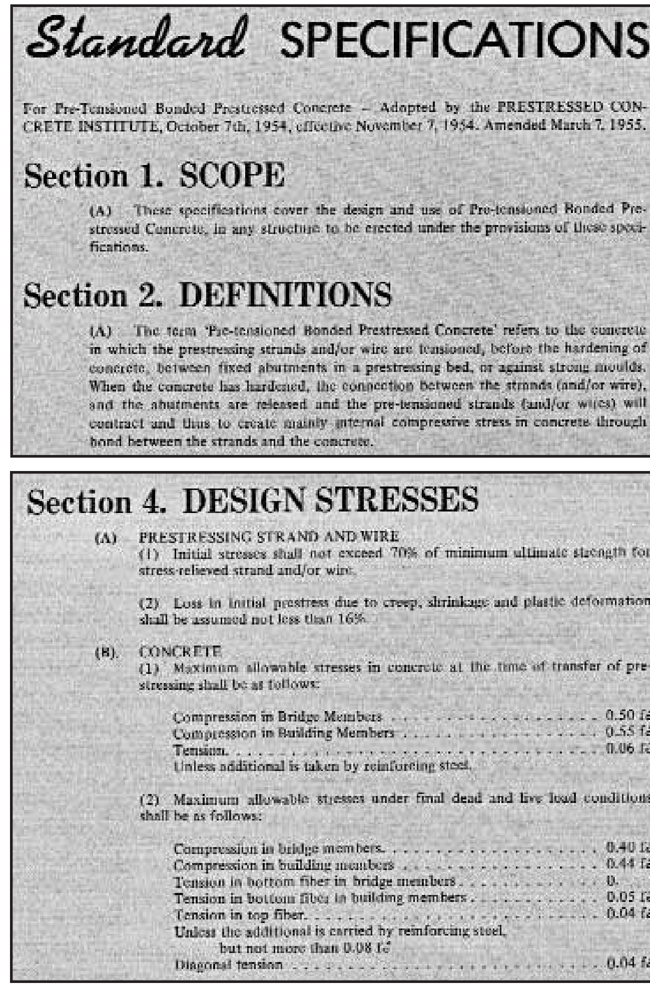


Fig. 1. U.S. Bureau of Public Roads published the *Criteria for Prestressed Concrete Bridges* in 1954.



Standard SPECIFICATIONS

For Pre-Tensioned Bonded Prestressed Concrete – Adopted by the PRESTRESSED CONCRETE INSTITUTE, October 7th, 1954, effective November 7, 1954. Amended March 7, 1955.

Section 1. SCOPE

(A) These specifications cover the design and use of Pre-tensioned Bonded Prestressed Concrete, in any structure to be erected under the provisions of these specifications.

Section 2. DEFINITIONS

(A) The term 'Pre-tensioned Bonded Prestressed Concrete' refers to the concrete in which the prestressing strands and/or wire are tensioned, before the hardening of concrete, between fixed abutments in a prestressing bed, or against strong moulds. When the concrete has hardened, the connection between the strands (and/or wire), and the abutments are released and the pre-tensioned strands (and/or wires) will contract and thus to create mainly internal compressive stress in concrete through bond between the strands and the concrete.

Section 4. DESIGN STRESSES

(A) PRESTRESSING STRAND AND WIRE

(1) Initial stresses shall not exceed 70% of minimum ultimate strength for stress-relieved strand and/or wire.

(2) Loss in initial prestress due to creep, shrinkage and plastic deformation shall be assumed not less than 16%.

(B). CONCRETE

(1) Maximum allowable stresses in concrete at the time of transfer of prestressing shall be as follows:

Compression in Bridge Members . . . . 0.50 f'c
Compression in Building Members . . . . 0.55 f'c
Tension. . . . . 0.06 f'c
Unless additional is taken by reinforcing steel.

(2) Maximum allowable stresses under final dead and live load conditions shall be as follows:

Compression in bridge members. 0.40 f'c
Compression in building members . . . . 0.44 f'c
Tension in bottom fiber in bridge members . . . . 0.
Tension in bottom fiber in building members . . . . 0.05 f'c
Tension in top fiber. . . . . 0.04 f'c
Unless the additional is carried by reinforcing steel,
but not more than 0.08 f'c
Diagonal tension . . . . 0.04 f'c

Fig. 2. PCI's first *Specifications for Pretensioned Bonded Prestressed Concrete Products* (1954).

concrete as a material. During Engineers Week, I participated in a student science project involving plexiglass blocks and an all-thread tensioning rod. This project gave me some insight into the principle of prestressing.

While I was at the University of Nebraska, I enrolled in the Air Force ROTC, which committed me to a two-year service in the U.S. Air Force after graduation. I graduated with a BS degree in civil engineering in January 1954 and then briefly worked for the Missouri Pacific Railroad before being called up into service by the U.S. Air Force. From 1954 to 1956, I was stationed in West Palm Beach, Florida, where I worked as a personnel officer, supply officer and installation engineer at the Palm Beach Air Force Base. It was in West Palm Beach that I met and married my wife, Joan.

Shortly after fulfilling my obligations to the U.S. Air Force in 1956, I applied and was accepted by the Harvard Business School. However, instead of going back to college for another degree, I decided, instead, to take a sales engineer job offered to me by R. H. Wright & Son, Inc. (a construction company involved in the precast, prestressed concrete business) in Fort Lauderdale. My lifelong friend Mac Taylor was the person who hired me. The company was managed by George Ford, second president of the newly formed Prestressed Concrete Institute. The decision to work at R. H. Wright & Son transformed my entire life and set me on a new and exciting career.

But before I digress any further, let me provide a brief background of the state of the precast/prestressed concrete industry in the United States before I arrived on the scene in 1956.

Although prestressed concrete was basically a European invention,[1] early applications of prestressing had occurred in the United States. For example, in the 1940s, the Preload Corporation (the same company that fabricated the girders for the Walnut Lane Bridge) was building concrete tanks with circumferentially wrapped post-tensioned wires.

Also, in the 1940s, Raymond Concrete Pile Company (later renamed Raymond International) was making prestressed concrete piles for supporting oil platforms in the Gulf of Mexico.

The piles were made like a string of beads. A concrete pipe machine made cylinders with cores in them, and then, the pipes were lined up on a roller/conveyor type apparatus and a group of wires was threaded through the cores in the walls of the pipes, much like compressing a string of beads.

Next, the wires were tensioned and locked off in a temporary anchorage, and then the cores were pressure grouted. After the grout hardened, the


BOARD APPOINTS ASSISTANT EXECUTIVE SECRETARY

NORMAN L. SCOTT TO WORK WITH COL. KORN

At its most recent meeting in New Orleans, the Board of Directors voted to hire Col. Martin P. Korn as a Consultant to the Prestressed Concrete Institute effective January, 1960. He is currently Executive Secretary. This action was taken to free him from administrative duties and utilize his talents and broad professional experience to the best interest of the INSTITUTE. To accomplish this, the Board voted to hire an Assistant Executive Secretary who would become Executive Secretary January 1, 1960, when P.C.I. headquarters moves to Chicago.

Fig. 3. Announcement of Norm Scott's appointment as assistant executive secretary of PCI (March 1959).

anchorages were cut off and the tensioned wires transferred the prestress like in a pretensioned member. These piles were later used in the foundation of the Pontchartrain Causeway crossing Lake Pontchartrain near New Orleans, Louisiana.

The major breakthrough in prestressed concrete came in 1949 with the construction of the Walnut Lane Bridge in beautiful Fairmont Park, Philadelphia, Pennsylvania. The fact that such a large bridge was being tested and built by a very novel method of construction brought the project considerable publicity which quickly spread across North America.

Designed by Professor Gustave Magnel of Belgium, the bridge had a 160 ft (48.5 m) main span, which is quite long even by today's standards. The prestressing steel used was 0.276 in. (7 mm) diameter, stress-relieved wire units. Seven-wire strand was still in the experimental stage and in limited use. (For further details on the design, testing, and construction of the Walnut Lane Bridge, see Reference 2.)

It is interesting to note that three pioneers of our industry were involved in the Walnut Lane Bridge – Charles Zollman (a former student of Magnel) was in charge of the construction, Arthur Anderson performed the instrumentation on the test girder, and Ted Gutt drafted the construction drawings. The publicity and excitement generated by the construction of this bridge was largely responsible for launching the precast, prestressed concrete industry.

About the same time as the construction of the Walnut Lane Bridge, Ross Bryan, another industry pioneer, designed an 80 ft (24.4 m) long two-span segmental bridge (the Turkey Creek Bridge) in Madison County, Tennessee. This bridge, completed in 1950, was made using special machine-made concrete blocks post-tensioned together. However, this bridge is only of historical interest today. Because of its limitations, this bridge did not have the same impact on future construction as the Walnut Lane Bridge.

Shortly after the successful completion of the Walnut Lane Bridge (1950), the First United States Conference on Prestressed Concrete was held at the Massachusetts Institute of Technology in Cambridge, Massachusetts, in August 1951. The proceedings of this conference basically summarized all the pertinent information that was learned from the Walnut Lane Bridge, Turkey Creek Bridge, and other notable structures in North America as well as on-going research. One interesting paper presented was the one given by Ben Baskin, then chief engineer of Concrete Products Company of America, who discussed how seven-wire strand was being used to pretension bridge decks in Pennsylvania.

Another source of information was promotional material produced by Stressteel Corporation on post-tensioned, prestressed concrete girders which were being used in the construction of the Lower Tampa Bay Bridge. This bridge was designed by Bill Dean, then the chief bridge engineer for the Florida State Road Department.

Pretensioned concrete is believed to have been developed by Eugene Hoyer in Germany in the late 1930s using high strength piano wires. However, no one in this country or in Europe got very excited about going into a precast, prestressed concrete products business pretensioning with piano wire. A more practical method to pretension concrete was definitely needed.

That answer came in May 1949 after Baskin had visited a precasting plant near London, England, where he observed the fabrication of short-span pretensioned joists and planks using 2 mm (0.076 in.) diameter piano wires. Baskin realized then and there that if he were to succeed in producing long-span prestressed concrete members he would need a more substantial type of prestressing steel. The key to this dilemma, of course, was the development of seven-wire prestressing strand.

Upon his return to the United States, Baskin persuaded American Steel and Wire (a U.S. Steel subsidiary) to develop a $^1/_4$ in. (6.3 mm) diameter seven-wire strand. He purchased the strand and in the summer of 1949 Baskin's plant in Pottstown, Pennsylvania, became the first pretensioning plant in the United States to use seven-wire strand for prestressing bridge members. Concrete Products Company of America was later purchased by American-Marietta Co.

This development gave entrepreneurs what they needed to go ahead with pretensioned, precast concrete as a mass production business. In 1952, the Perlmutter brothers (Jack and Leonard) and Mike Altenburg built a prestressing plant in Denver, Colorado. Meanwhile, Art Anderson had moved back to his hometown in Tacoma, Washington, to build a prestressing plant with his brother, Tom. This plant was completed and ready for production in 1951.

Within months of American Steel and Wire coming up with seven-wire strand, John Roebling Sons Company in Trenton, New Jersey, became the dominant supplier of prestressing strand. Other pioneering companies were Union Wire Rope Company in Kansas City and Colorado Fuel and Iron in Pueblo, Colorado. However, later these companies had competition from foreign companies with the capability to supply top quality strand.

Based primarily on the work of E. L. Erickson of the U.S. Bureau of Public Roads (the forerunner of the Federal Highway Administration) published in 1954 the *Criteria for Prestressed Concrete Bridges.*[3] This document (see Fig. 1) was to have a major impact on the future development of prestressed concrete bridges in the United States.

About the same time, the Joint ASCE-ACI Committee 323 was hard at work developing its report on Prestressed Concrete. Professor Chester Siess of the University of Illinois at Champaign-Urbana had a prominent role in developing this report, which would play a decisive role in including provisions for prestressed concrete in the 1963 ACI Building Code.

Then, in the mid-fifties, T. Y. Lin came out with a book titled *Design of Prestressed Concrete Structures* – the first American textbook on prestressed concrete.[4] This book, which has gone through several revisions since it was first published, had a profound effect on the practice of prestressed concrete in North America.

The end result of all this activity is that a number of precast, prestressed concrete plants had sprouted in Florida and other states, and that their products were being used not only for bridges but also for buildings and other structures. One important ingredient was missing, however, and that was a central organization to represent this fledgling new industry. The other important item was that provisions for precast/prestressed concrete needed to be included in the ACI Building Code and other legal specifications.

The situation changed dramatically when on June 18, 1954, six companies convened in Tampa, Florida, to form the Prestressed Concrete Institute (PCI). The six founding members were:

Fig. 4. PCI Fifth Annual Convention at Deauville Hotel, Miami Beach, Florida, November 3, 1959. From left to right table near side: Jo Bryan (wife of Ross Bryan), Hubert Persons (PCI's first publications director), Ella Maude Gray (wife of Ashton Gray), Ashton Gray (PCI's third president), Jo Clark (wife of Elmer Clark), Elmer Clark (PCI's tenth president). From left to right, table far side: Ross Bryan (Ross Bryan Associates), Robert Lyman (PCI's eighth president and third executive director), Coletta Lyman (wife of Robert Lyman), Norm Scott (PCI's second executive secretary), Joan Scott (wife of Norm Scott), Charles Scott (PCI's thirteenth president), Eva Scott (wife of Charles Scott).

- Cone Brothers (Douglas P. Cone)
- R. H. Wright & Son (George Ford)
- Duracrete (J. Ashton Gray)
- West Coast Shell Corp. (Sam Johnson)
- Lakeland Concrete (Harry Edwards)
- Gordon Bros. (Francis Pipkin)

Douglas Cone of Cone Brothers was made president and Harry Edwards secretary-treasurer in the initial year of 1954-55. George Ford served as president in 1955-56; J. Ashton Gray served in 1956-57, and Peter Verna from North Carolina followed in 1957-58.

The first PCI Convention was held at the Lago Mar Hotel in Fort Lauderdale, April 21-22, 1955. About 300 engineers, architects, contractors and producers attended this convention.

The early leaders of PCI recognized that prestressed concrete is an engineered product which needs the active participation of professional engineers. There were six classes of members – Active, Associate, Professional, Junior, Student and Honorary. Charles Zollman was appointed PCI's first chairman of the Technical Activities Committee (TAC).

The stated objectives of PCI were to develop standard specifications for prestressed concrete products for architects and engineers; to conduct fire tests for roof and floor slab products; to develop and promote standardization of beam sections for bridges; and to produce a technical journal and newsletter.

Some of these objectives were quickly fulfilled:

- On November 7, 1954, the PCI published the first *Specifications for Pretensioned Bonded Prestressed Concrete Products* (see Fig. 2).[5] The chairman of the committee producing this document was Harry Edwards.
- The first newsletter, *PCItems*, was published in 1955.
- The PCI JOURNAL was inaugurated in June 1956 with the first issue displayed at the second PCI Convention at the Hollywood Beach Hotel in Hollywood, Florida.

This was the scenario when I arrived in 1956 at the R. H. Wright

Fig. 5. Meeting in San Diego, California (1973). Front row, left to right: Gene Garson (secretary-treasurer of Precast/Prestressed Concrete Manufacturers of California), Charles Walter (PCI president, 1973), Michael Kupfer (San Diego Prestressed Concrete). Back row: Burr Bennett (PCI executive director), Norm Scott (CEG), Ross Rudolph (Basalt Precast).

Company. From this point on, my education in prestressed concrete, and particularly precast, pretensioned concrete, was immediate and took off at an accelerated pace. After all, the precast/prestressed concrete industry was still in its infancy but most of the action was taking place in Florida.

In the mid-fifties, much of the technical information came from Leap Associates, a design firm founded by Harry Edwards in the early fifties. Harry was a visionary with a flair for promotion but he also had a solid engineering background. The firm was one of the first to offer engineering services. Although the double tee was first developed by Prestressed Concrete of Colorado with a copyrighted name "Twin Tee" in 1952, Harry was largely responsible for promoting the product nationwide by preparing and distributing load tables shortly afterwards. It is doubtful that Harry knew about the Perlmutters' twin tee initiative. In both parts of the country the double tee section evolved from the notion of putting wings on a channel section to cover more area at less cost.

Another firm providing technical information was the Freyssinet Company, which was headquartered in New York City and was headed by Randall DuBois. In addition to selling post-tensioning tendons, anchorages and other hardware, the company also provided engineering services like Leap Associates and Ross Bryan. Irwin Speyer, Jim Libby and Eugene Smith were employed by Freyssinet in the fifties.

At that time, not all of the precast products being manufactured were prestressed. For example, Price Brothers was producing Flexicore slabs using only mild reinforcing steel. Some companies produced non-prestressed double tees while others fabricated reinforced (non-prestressed) concrete bridge members. Of course, by introducing prestressing steel, much longer spans and better crack control could be attained.

A major breakthrough occurred in 1957 with the construction of the 24-mile (38 km) long Pontchartrain Causeway over Lake Pontchartrain near New Orleans, Louisiana. This was an innovative project which decisively showed the advantages of repetitive mass-produced members. A two-lane highway bridge could be designed with precast, prestressed concrete members extending the complete span and width of the bridge. The 50 ft (15.2 m) spans were made in huge pieces going from pier to pier. The project was a joint venture between Raymond International, Brown and Root, and T. L. James.

Earlier still, several other developments were taking place. As mentioned earlier, Harry Edwards developed the first specifications for pretensioned bonded prestressed concrete products less than six months after the formation of PCI (see Fig. 2). This document was presented at the first PCI Convention in Fort Lauderdale in April 1955.

Also, Bill Dean and Charles Zollman developed standards for pretensioned I-beams with spans ranging up to 60 ft (18.3 m). Later, almost single-handedly, Dean developed the AASHTO-PCI I-beam standards. There were several other persons who also made major contributions including Randall Alexander, chief bridge engineer for Texas, J. C. Rundlett at the Boston Department of Public Works, W. C. Cummings and M. Fornerod at Raymond, Ed Schechter of Stressteel, and Forest Burch, Lloyd Hill, Kent Preston and Pat Patterson of Roebling.

Meanwhile, in 1956, the PCI realized that it needed a full-time headquarters staff and a permanent location. It chose Martin P. Korn, a retired army colonel, to be its first executive secretary. Boca Raton, Florida, became PCI's headquarters.

Korn was a former consulting engineer with design and construction experience who was also an author with a flair for writing and an authority on steel rigid frame structures. He quickly became very enthusiastic about prestressed concrete and actually built an office next to his home in Boca Raton using prestressed double tees. This imposing facility served as the first PCI Headquarters.

In 1956, the PCI JOURNAL was being produced by the Department of Civil Engineering of the University of Florida at Gainesville. The editors were Professors Ralph Kluge, Alan Ozell, Donald Sawyer and Paul Zia.

PCItems was edited by Korn and produced by the Peter Larkin Agency, as were other promotional materials.

In 1959, at the suggestion of PCI President George Ford, I became the understudy of Korn with a view to becoming PCI's second executive secretary (Fig. 3) and moving the Institute's headquarters to Chicago, Illinois. The anticipated advantages of moving to Chicago were many, but the primary motives were a central location in the United States and proximity to the Portland Cement Association (PCA) and other concrete related associations. This move was accomplished in December 1959.

My first task in Chicago was to visit as many PCI Producer Members as possible throughout the country within a short two-month period. I took my wife Joan on this arduous journey, ending up at the Fifth Annual PCI Convention in Miami Beach, Florida, November 2 to 7, 1959 (see Fig. 4). This gave me a wonderful opportunity to also meet non-member producers and especially to meet some of the early pioneers of the industry. On this trip, I remember specifically talking to Art Anderson, founder of Concrete Technology Corporation, Ted Gutt, then at the George Rackle Company, and Ben Gerwick, Jr., at Ben C. Gerwick Company.

Over the next decade and beyond I got to meet many other wonderful people in the industry (see Figs. 5 and 6), and also got to visit many interesting places (see Figs. 7 to 9).

One other important responsibility entrusted to me was to conduct seminars on precast/prestressed concrete across the United States. To help me in this endeavor, in July 1960, I hired my good friend Tom D'Arcy as technical director and publications director at the Chicago office. In addition to his many other duties, Tom was editor of the PCI JOURNAL and *PCItems*.

During the early years (1950s and 1960s), the Portland Cement Association (PCA) showed considerable interest in the prestressed concrete industry and especially in what this new technology could do for them. In 1951, Alfred Parme and George Paris published a paper on how to design continuous prestressed concrete flexural members.[6]

This was PCA's first attempt to write an analytical paper on prestressed concrete. Basically, it took the analogy of a catenary-shaped cable and looked upon it as providing an upward uniform load counter-balancing the applied downward vertical loads. Later, T. Y. Lin took this same concept, further modified it, and called it the "load balancing method."[7] Lin was widely credited for popularizing this design method in the design community.

Fig. 6. PCI 21st Annual Convention, Caesars Palace, Las Vegas, Nevada, September 22, 1975. Left to right: Bob Beerbower (Price Brothers Company), Norm Scott (CEG), Joan Scott, Marge Beerbower.

Some of the other familiar names from PCA who were involved with prestressed concrete at that time included Armand (Gus) Gustaferro, Dan Jenny, and Burr Bennett. During this time period, Thor Germundsson was head of the PCA Structural Bureau. He was a very energetic and progressive engineer. Also, at the time, Jack Janney, a recent graduate from the University of Colorado, was doing laboratory tests at the PCA on the behavior of bonded and unbonded prestressed concrete beams.

As early as the 1940s, the American Concrete Institute (ACI) had a committee working on provisions for prestressed concrete but had not yet published a report on the subject. The committee, called ACI-ASCE Joint Committee 323, was for several years headed by W. C. Cummings at Raymond International. In the mid-fifties, PCA assigned Armand Gustaferro to the task of putting the language of the document into a practical design format. Later, Burr Bennett became committee secretary as the report moved toward formal publication in 1959. (Burr was later to become PCI's fourth executive secretary.)

The committee document was called "Tentative Recommendations for Prestressed Concrete" and covered both bridges and buildings. Although much of the report was written at PCA, the main credit of the published report came as an ACI-ASCE joint effort. By mutual agreement, this report was also published in the PCI JOURNAL.[8]

It should be appreciated that during the fifties and sixties most of the ACI Committee work (especially the ACI 318 Building Code) was actually done by the PCA.

In 1957, in conjunction with the ACI Convention in San Francisco, California, the first World Conference on Prestressed Concrete was held. This conference was organized by T. Y. Lin and several other professors from the University of California. More than 1200 people from all over the world attended this conference.[9]

As important as the MIT conference had been five years earlier, the San Francisco conference was even more significant. In addition to several very important papers, prestressed concrete was beginning to get extensive press coverage, especially by *Engineering News-Record*.

This was a time when the Illinois Toll Road was just getting started, the Pontchartrain Causeway was being constructed, the Garden State Parkway

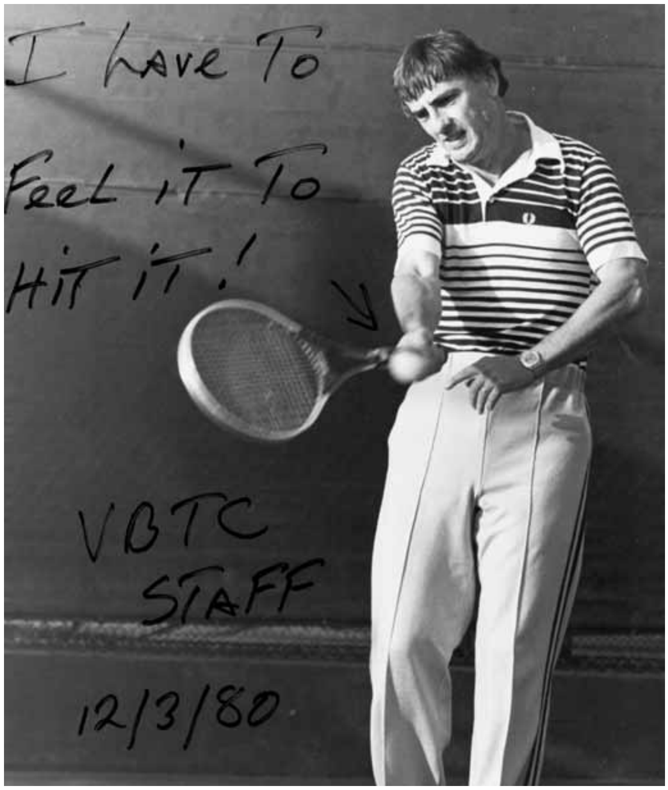


Fig. 7. Norm Scott was and still is a very accomplished tennis player. He developed his tennis skills while he was in Florida, and when he came to Chicago he built his own tennis court at his home in Glenview. This picture was taken at the Vic Braden Tennis Academy in California in 1980.

Fig. 8. Norm and Joan on a recent vacation in New Zealand.

had been completed, and several other major prestressed concrete projects were being constructed in Florida, Massachusetts, Texas and California.

Even with growing interest in the recognition of precast/prestressed concrete, many precast industry leaders were not comfortable with the ACI-ASCE document being called “Tentative” and its slowness in being adopted by the ACI Building Code. Many precasters felt the document lacked legitimacy even though the Bureau of Public Roads had already used prestressed concrete in their highway bridge projects.

Since ACI did not initially respond to the need for a definitive code on prestressed concrete, Peter Verna aggressively pushed the notion of a PCI building code and T. Y. Lin actually wrote one. This “code” became a major motivation for ACI to do something. Indeed, ACI did not really want PCI in the code-making business, so a compromise was reached. ACI agreed to incorporate prestressed concrete in its 1963 Code and to have four members from PCI on the committee to draft it. This group was composed of Armand Gustaferro, Ross Bryan, T. Y. Lin, and Irwin Speyer.

The inclusion of provisions for prestressed concrete for the first time in the 1963 ACI Code[10] was of tremendous importance to the industry at the time and really helped it move forward because it was then officially legal to design and build with prestressed concrete. For more information on the history of building code provisions for prestressed concrete, see Reference 11.

The 1950s were a very interesting time period. With increasing competition in the marketplace, the industry had to come up with a selection of products and systems that made sense for bridges as well as for buildings. Again, a number of developments and opinions were going on that would influence the use and direction of these products and systems.

The Walnut Lane Bridge had used a bulb tee with a wide flange at top and a narrower bottom flange where the main prestressing reinforcement was located. A little later, Concrete Products of America, later renamed American-Marietta, was promoting a product called a box beam, placing the units side by side. The company had some success selling these box beams in Pennsylvania, Michigan, Indiana and Illinois.

At about the same time, the Bureau of Public Roads (BPR) and Bill Dean in Florida were designing bridges with I-beams which had a cast-in-place concrete deck. Dean was at odds with E. L. Erickson, contending BPR had too many standard sections and he wanted fewer. Dean, however, did give Erickson due credit for his leadership in providing a federal endorsement to the use of prestressed concrete for bridges.

Charlie Zollman, representing PCI, along with Bill Dean who represented the American Association of State Highway Officials (now called the American Association of State Highway and Transportation Officials) brought key people in AASHO together with PCI producers and created a set of I-beam standards for bridges. They settled on only four sections: Types I, II, III, and IV.

Everyone went along with this approach except for Art Anderson, who wrote a scathing criticism of these standards which was published by *Engineering News-Record* (ENR).[12] In essence, he showed that the bulb-tee section was structurally more efficient than the I-section and, therefore, advocated the use of the bulb-tee girder which was being used in Washington and Oregon.[13] In retrospect, Anderson was right. Indeed, today, the new bulb-tee girder standards are gradually replacing the old AASHTO–PCI I-beam sections because the bulb tee is more efficient and much more attractive than the I-beam.

Although Anderson's letter to ENR brought a flood of letters from readers, he eventually lost his battle regarding the bulb tee as a nationwide standard. Dean said he did not want the bulb tee because he regarded it as a "delicate" section. Earlier, Dean had a poor experience with a 4 in. (102 mm) web section on his first prestressed concrete bridge over the Lower Tampa Bay.

In the fifties, Dean maintained that quality control could not guarantee the kind of precision necessary to make thin-web bulb tees. On the other hand, Anderson believed fervently that the industry was not taking proper advantage of the potential of prestressed concrete, that is, the bulb sections would be lighter, span farther and be more economical if done his way. Anderson and a few others continued to use the bulb tee in the Pacific Northwest while Dean's I-beam standards were almost immediately accepted in Florida and twenty other states.

This trend continued in the early stages of development of bridges for the Interstate Highway Program, which began in 1956 and continued into the seventies and eighties. However, near the end of the Interstate Program, there were still many bridges yet to be built. The steel industry started winning jobs by convincing state bridge engineers that 100 ft (30.5 m) long spans required three intermediate piers. This solution, of course, made crossings less safe for underneath traffic and also was not very attractive. With spans of 120 to 135 ft (36.6 to 40.2 m), steel girders could solve the problem with only one interior pier.

A product development problem forced the industry to come up with a solution because the steel competition was taking too much of the bridge market. PCI and AASHTO revisited the advantages of the bulb tee and developed the Type V and VI girders in 1968, but they were still too heavy.

By 1987, PCI waged the battle alone and issued standards which were much closer to those advocated earlier by Art Anderson. Improved production techniques and better quality control made this possible. So, the bulb tee was reintroduced and prestressed concrete recaptured the long span bridge market because it now had a product that could compete with steel and had aesthetic durability advantages in addition.

The same situation as for bridges was also evolving for buildings. From the beginning, the double tee has emerged as the industry's most popular product. And yet, it has been challenged time and again. Surely, there was a better way to span floors and roofs. In fact, many different structural systems have been tried, but most have failed to stay the course.

Fig. 9. Norm and Joan enjoy a relaxing walk on Marco Island.

In the early sixties, some practitioners looked to what Europe was doing. In their search for a new product, Material Service Corporation in Chicago sent a marketing-technical team to the old Soviet Union to see what the Russians were doing. The country was in the midst of a state-sponsored housing building program and what impressed the Americans the most was the use of a wide lightweight box beam.

Upon their return from overseas, Material Service embarked on the development of a 24 in. deep by 8 ft wide (0.61 x 2.44 m) four-cell box beam with a top flange only $1^1/_2$ in. (38 mm) thick. They called the new product "Dynacore." It spanned a long distance and it looked very elegant. Unfortunately, it was also exceedingly expensive to fabricate and, therefore, could not compete in the marketplace. Several other "miracle" products also came and went.

In the sixties, T. Y. Lin & Associates, a consulting firm in Los Angeles, California, developed a single tee that was 8 ft wide and 3 ft deep (2.44 x 0.92 m). Many producers bought

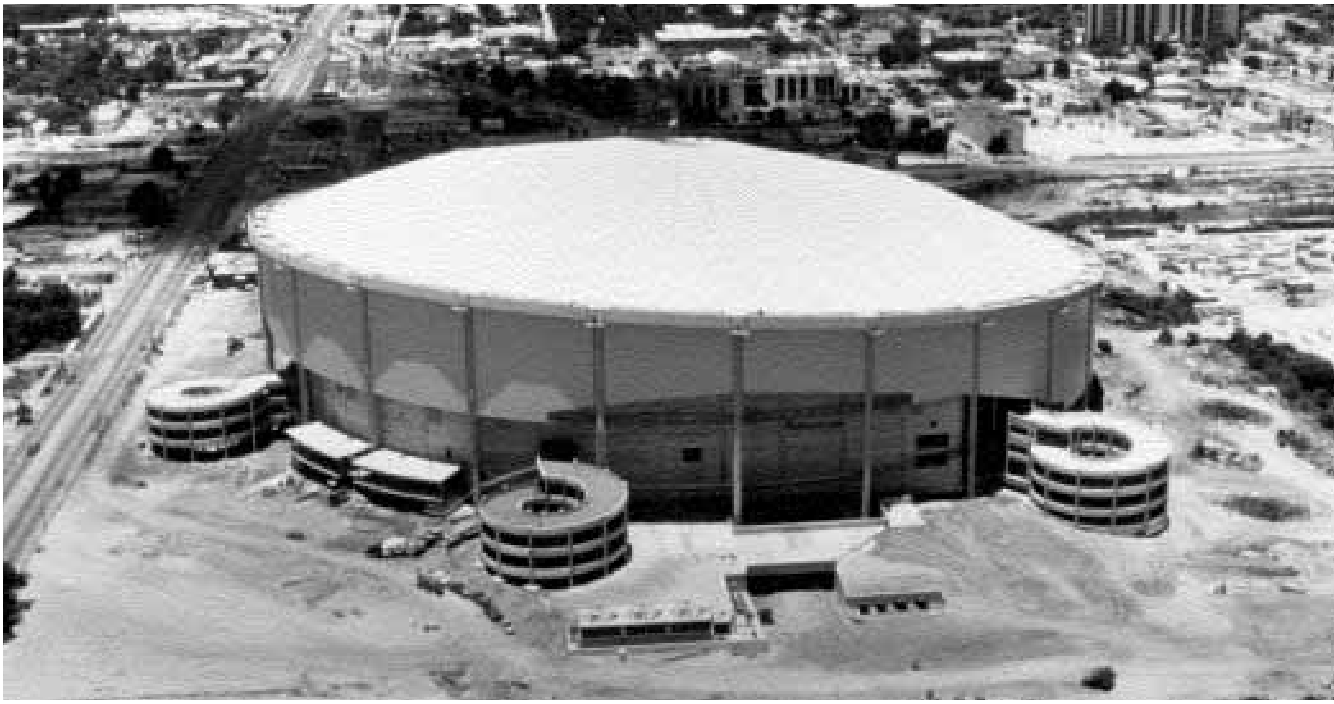


Fig. 10. Florida Suncoast Dome, St. Petersburg, Florida (1989). This project was a joint CEG-Illinois-Texas job.

forms to fabricate this single tee, which was also called a "Lin tee." Despite its elegance and eye appeal, this product did not survive the marketplace because it did not efficiently use materials and labor. The product was also unstable during storage, hauling and erection. It should be mentioned that some producers today use a modified single tee to span the roofs of water tanks.

On the other hand, some producers continued to have "deep faith" in the double tee. Over the years, the product became successively wider and deeper. And with each leap forward, the double tee became more efficient and economical, and thus guaranteed its place in the marketplace for spans ranging from 35 to 100 ft (10.7 to 30.5 m). Astonishingly, the double tee is not widely used in Europe except for Italy and the Scandinavian countries. In retrospect, we might say the double tee is an American phenomenon.

From a historical viewpoint, only those products that withstood the "test of time" have survived. The single tee, Dynacore, mono-wing, gull wing, Y-section, and wedge joist all lost out to the double tee.

Hollow-core slabs have a similar success story as the double tee. In 1953, Henry Nagy in Milwaukee, Wisconsin, bought a slip-form machine in Germany and had it shipped to the United States. The machine cast concrete over tensioned wires to extrude a hollow-core product. The original machinery was in fact an old rusty machine which used piano wires for prestressing steel.

No longer using piano wires, Nagy employed $^1/_4$ and $^3/_8$ in. (6.3 and 9.5 mm) diameter seven-wire strand that had only recently been developed. He called the resulting 1 meter (3.28 ft) wide product "Spancrete," and it was the first prestressed concrete hollow-core slab produced in North America.

Several practitioners tried to come up with their own 3.28 ft (1 m) wide extrusion machine. One of the more successful hollow-core products was "Flexicore," but even this manufacturer went out of business a few years ago.

In the early days, Harry Edwards got involved in the hollow-core slab business, but his venture was not entirely successful. The problem was that not enough producers wanted to buy these machines and invest their resources in the high degree of quality control that was required. The end result is that Spancrete is still today one of the best hollow-core slab products available in terms of its quality, dimensional control and finish.

In retrospect then, the two most important building products the industry has today is the double tee and the hollow-core slab.

Over the years, the PCI Plant Certification Program has had a major effect in improving overall industry quality. The certification program was first proposed in 1958 but not for the most noble of purposes. Early proponents of the program thought it would keep "backyard operators" out of the business and thus restrict competition.

By 1963, Bill Dean had retired from the Florida DOT and, while working for a private consulting firm, wrote the first PCI Quality Control Manual. In 1965, PCI hired Ross Bryan & Associates to be the certifying agency. At the time, Ross Bryan stated that the Plant Certification Program had to be meaningful or else he was not going to have anything to do with it. His early resolve has guided the program ever since. Today, it is a nationally recognized program which is obligatory for every PCI Producer Member.

In 1963, I left the PCI as executive secretary and took a position as general manager of Wiss, Janney, Elstner and Associates (WJE). This firm then, as now, is engaged in structural consulting, forensic engineering, failure investigation, research, development and

Fig. 11. Connecticut Tennis Center, New Haven, Connecticut (1991).

testing. Jack Janney and Dick Elstner (two of the founders of WJE) were two persons who I highly respected for their integrity and dedication. I stayed at WJE for the next three years.

Ultimately, my heart and passion were in the precast/prestressed concrete business. In 1966, I took the bold step of establishing my own consulting business and founded The Consulting Engineers Group, Inc. (CEG), in Glenview (a north suburb of Chicago). From the beginning, the mission of CEG has been to service the needs of the precast/prestressed concrete industry.

In a little more than a year later, I hired Jerry Goettsche as our first full-time employee. Jerry had previously worked for an architectural/engineering firm and had recently applied for a sales engineering position with a precaster who happened to be my client. Jerry decided he was not interested in the sales position but liked CEG's vision and the future promise it would hold.

It was not long afterwards that Les Martin also joined the firm. Les and I had met earlier as classmates at the University of Nebraska. Les had worked for structural engineering firms in Omaha, Nebraska, and Denver, Colorado, and later was employed by the PCA in Nebraska and Iowa before joining CEG.

Fig. 12. Penn Street Parking Structure, University of Maryland, Baltimore, Maryland (1992).

A little later, Armand (Gus) Gustaferro joined CEG. Gus was already well recognized as an authority on concrete materials and fire issues as well as prestressed concrete. At the time, he was head of the Fire Research Laboratory at PCA. Earlier, he had managed one of the precasting plants that produced prestressed concrete bridge girders for the Illinois Toll Highway.

My next partner was Tom D'Arcy. Of course, I knew Tom from the time we worked together at the PCI office

Fig. 13. In foreground, Atlanta Braves Baseball Stadium (formerly the Olympic Stadium), Atlanta Georgia (1996). Background left corner is the Georgia Dome which was also designed by CEG. Note that the old Atlanta-Fulton County Stadium (middle of picture above front stadium) has since been torn down.

Fig. 14. Ravens NFL Stadium, Baltimore, Maryland (1998).

in Chicago. After leaving PCI, he worked for four precast producers in North Carolina, Massachusetts, Colorado and Texas. In 1982, Tom opened the CEG Texas office.

Walt Korkosz originally worked in the Chicago office and then went to Texas where he is now president of CEG-Texas. Larbi Sennour is executive vice president there. Mike Malsom had been a roommate of Walt's at the University of Illinois. It was at Walt's suggestion that Mike applied to CEG. Currently, Mike is president of CEG-Illinois and Jeff Carlson, who joined the firm in 1987, is executive vice president. Mike is now board chairman and CEO of the parent CEG.

Over the years, CEG has grown and diversified to meet the varied needs and applications of the precast/prestressed concrete industry. For example, new technology had to be developed with the emergence of justice facilities in the eighties and stadiums in the nineties.

Today, the Chicago office has 32 personnel and Texas has 33. In addition, CEG has satellite offices in Fort Lauderdale, Florida, Bella Vista, Arkansas, Horseshoe Bay, Texas, Apple Valley, Minnesota, and Cincinnati, Ohio.

Some of the proudest jobs CEG has been involved with include the first all-precast major league baseball stadium (the Florida Suncoast Dome) in St. Petersburg, Florida (see Fig. 10). This job was a joint effort between the Chicago and Texas offices of CEG. Originally, the stadium was planned to be built using cast-in-place concrete, but Pomco sold the job in precast, prestressed concrete, and then CEG made it happen from a design viewpoint. Tom, Les, Jerry, Walt and I accomplished this task over a long weekend in San Antonio in 1988. This project won Tom D'Arcy and Jerry Goettsche the Lyman Award for their article in the January-February 1990 PCI JOURNAL.

Another interesting project was the Connecticut Tennis Center in New Haven, Connecticut (see Fig. 11). This job used a variety of precast/prestressed concrete components as well as some architectural precast concrete. This project won Les Martin the Lyman Award for his article in the January-February 1992 PCI JOURNAL.

Of the many parking structures CEG has done over the years, the Penn Street Parking Structure for the University of Maryland in Baltimore, Maryland, proved to be one of the most interesting structures (see Fig. 12). This structure required considerable architectural treatment.

The list of CEG projects also includes the first all-precast prison for the State of Virginia; other precast modular prisons in other states; more than thirty major stadiums – in particular the Olympic Stadium in Atlanta, Georgia, with its baseball conversion (see Fig. 13); also, the Philadelphia Eagles Stadium in Pennsylvania because of coordinating the engineering for two different precasting companies. Another outstanding stadium is the Ravens NFL Stadium in Baltimore, Maryland (see Fig. 14).

Among the many important parking structures CEG has done is the Mall of America in Minneapolis, Minnesota (one of the world's largest parking structures) and the Midfield Terminal parking structure in Detroit, Michigan, the world's largest such structure (see Fig. 15). Another recent job is the Newark Airport, for which CEG was the engineer of record. One of the more notable justice facilities that CEG-Texas has done is the CCA California Prison in California City, California (see Fig. 16).

In the decade between 1951 and 1961, more than 230 precasting plants were built in the United States – far too many plants for them all to be profitable considering the industry was so young and prestressed concrete had not yet been totally accepted within the design community. Some of these companies failed while others merged. The number of plants peaked in about 1975 when there were about 500 plants. Today, that number has leveled off to about 280 plants.

A study of the market during the past 25 years shows that structural precast concrete has been gaining market share at about $3^1/_2$ percent per year while the rate is about 2 percent for architectural precast concrete. In the case of bridges, the market share is about a 3 to 4 percent rate of growth per year. If we use the U.S. gross domestic product of 3 percent per year as a frame of reference, we see that our

Fig. 15. Midfield Terminal parking structure (world's largest), Detroit, Michigan (2000). This project was a CEG-Texas job.

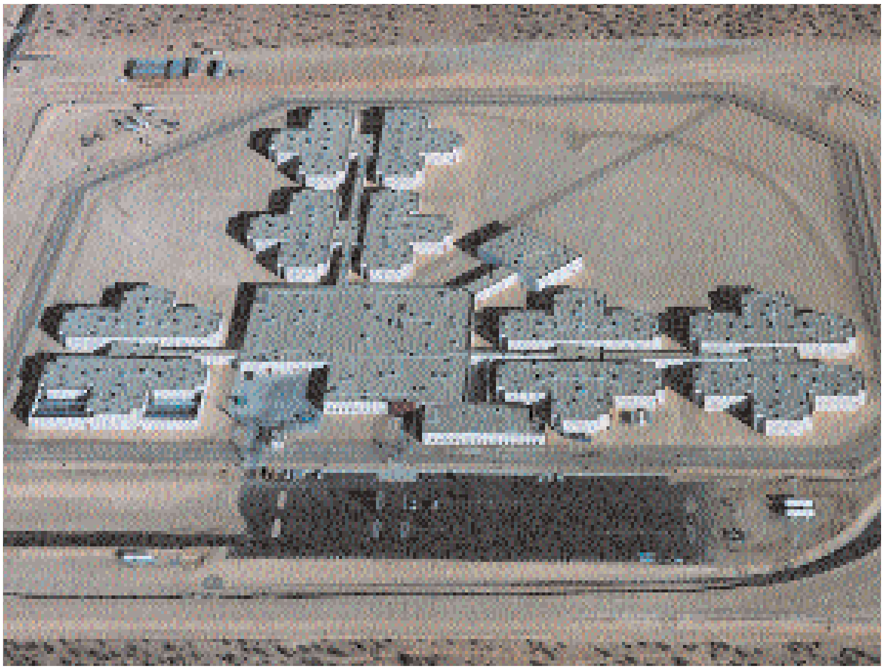
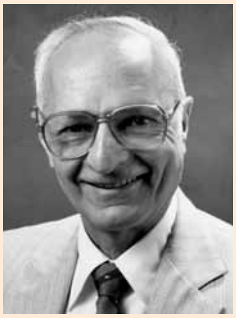


Fig. 16. CCA California Prison, California City, California (1997). This project was a CEG-Texas job.



Gus Gustaferro

Norm Scott

Les Martin

Tom D'Arcy

PROFESSIONAL PARTICIPATION AND RECOGNITION

Since its founding in 1966, The Consulting Engineers Group, Inc. (CEG) has devoted its entire focus in serving the precast/prestressed concrete industry. This involvement is best exemplified by the large number of CEG principals and personnel that participate in PCI Committee work and other allied professional organizations.

Gus Gustaferro served as the second PCI TAC chairman (Charles Zollman was the first TAC chairman). Gus was followed by Norm Scott, Les Martin and Tom D'Arcy. Scott, Martin, D'Arcy, Jerry Goettsche and Mike Malsom have all served on the PCI Board of Directors. Norm, Gus, Les and Tom have also served on important ACI committees dealing with the ACI Building Code, and other ACI committees on Prestressed Concrete and Precast Concrete.

D'Arcy is currently chairman of PCI's Research and Development Committee. Scott served as president of the ACI in 1983. In addition, other CEG personnel currently serve as chairmen or members of several PCI technical committees.

Martin has been the principal editor of the prestigious PCI Design Handbook on three separate editions, including the ground-breaking first and the current Sixth Edition under development. Gus is the author of the PCI Design Manual for Fire Resistance of Precast Prestressed Concrete, and D'Arcy is the principal author of the "PCI Standard Design Practice" and co-editor of the "Recommended Practice for Design and Construction of Precast Prestressed Concrete Parking Structures."

Scott, Gus, Martin, D'Arcy, Goettsche, Korkosz, Malsom and other CEG personnel have been authors of reports and papers that have been published in the PCI JOURNAL and other professional journals. Some of these articles have won national awards.

Very deservedly Gus, Scott, Martin and D'Arcy have won PCI's most prestigious award – the Medal of Honor. All four are also PCI Fellows. Scott has won the ACI Henry Turner Award (1993), the Henry Kennedy Award (1999) and the ACI Chicago Chapter Henry Crown Award (1996). In 2000, he was named a Distinguished Alumnus by the University of Nebraska, Department of Civil Engineering. Scott and Gus have also received the FIP Medal from the Fédération Internationale de la Précontrainte.

At ACI's recent 100th Year Anniversary Convention in Washington, D.C., in March 2004, Scott received the 2004 Wason Medal for most meritorious paper for his article "In Construction Who is Responsible for What?," which appeared in the May 2002 issue of *Concrete International*.

industry has been keeping pace with the general economy.

The challenge today is how to increase market share. Since structural steel and cast-in-place concrete can be designed by an architect or engineer almost single-handedly, the same is not the case for precast/prestressed concrete. More often than not, precast concrete needs the services of a specialty engineer. But before that stage is even reached, the precast option might well have disappeared. It all depends on the attitude of the architect/engineer and how well he or she is disposed to using precast concrete.

Part of the challenge is knowing how to network with decision makers who have knowledge about projects in the planning or, preferably, in the preplanning stage. The ideal situation is for a project to be headed by a contractor and a well-informed precaster who can engage in a meaningful discussion with the owner as early as possible. The objective then is to be able to get a "seat at the table" during the early stages of a project and be able to have the opportunity to show the owner and design team that a precast solution will not only result in a quality structure but will also save money.

The approach I advocate is partnering for quality design, which is outlined in an article I wrote in the November-December 1998 issue of the PCI JOURNAL.[14] The key here is that the architect or engineer needs to know that he or she does not have to be an expert in precast/prestressed concrete.

In other words, it is quite legal and

ethical for the engineer of record to delegate specialized engineering to a contractor, subcontractor, or an independent professional, such as a PCI Professional Member, as long as that work is carried out by an engineer registered in the state of the project. This requirement is important in solving the problem of responsibility and the issues that make design engineers feel uncomfortable.

Architects and engineers also need to know that precasters are interested in bidding on their jobs. That assurance is built on mutual trust and respect. This practice of mutual respect is best exemplified in the state of Colorado where competing precasters work with architects, engineers and owners for the benefit of all concerned. This special relationship with the design community needs to be fostered in other parts of the country. With more widespread partnering efforts, I believe that the market share of precast/prestressed concrete will increase significantly.

CONCLUDING REMARKS

During the past 50 years, the precast/prestressed concrete industry has built up an impressive record. From a zero sales volume in 1950, precast/prestressed concrete is today a multi-billion dollar industry. Across the country, there is a large variety of low-rise to high-rise precast/prestressed concrete structures to showcase with almost every imaginable type of application.

Today, architectural precast concrete cladding adorns the façade of many prestigious buildings as well as a multitude of other structures. About 70 percent of state-funded bridges are currently constructed with prestressed concrete. The majority of parking structures today are built using precast, prestressed concrete. For the most part, all these structures have shown excellent durability.

Over the years, the quality and workmanship of precast concrete products have improved and, in general, architects and engineers recognize precast concrete as a viable building material. Much of this success is due to the Plant Certification Program and to the PCI itself, which through its technical arm and especially its publications, has developed a body of technical knowledge that is credible to the design community.

What about the future? First, I believe that the precast industry possesses an engineered product that is very versatile, and, therefore, the industry's future is bright.

For the industry's long-term success, I suggest the following approaches be followed:

- Continue to cultivate a strong relationship with the design community.
- Encourage a partnering design approach whereby the precaster can gain a seat at the table during the early stages of a project.
- Foster total precast concrete structures in which the entire frame is composed of precast columns, beams, floor members, exterior finished members, stairs and elevator shafts.
- Where appropriate, integrate structural members with an architectural finish.
- In the case of bridges, also promote totally precast structures with the use of precast/prestressed girders, as well as precast decks and piers.
- For long-span bridges, use spliced bulb-tee girders for structural efficiency and aesthetics.

ACKNOWLEDGMENT

I wish to express my deep gratitude to Karen Goettsche for the time and patience she took interviewing me and to George Nasser, Editor Emeritus, for his many suggestions and assistance in modifying the original manuscript.

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