The Global Advance – Emerging Opportunities at Home and Abroad

Ben C. Gerwick, Jr.
Chairman
Ben C. Gerwick, Inc.
Consulting Construction Engineers
San Francisco, California
(Professor Emeritus
of Civil Engineering,
University of California at Berkeley)

For the past 30 years, **Ben C. Gerwick, Jr.**, has been chairman of his own consulting firm, which he founded in 1971. His firm provides worldwide engineering-marketing services in all phases of precast and prestressed concrete construction, particularly for bridges, foundations and marine structures. Recent projects include the King Fahd Causeway, Eurotunnel, Great Belt Bridges and Tunnel, Hibernia Offshore Platform and San Francisco Airport expansion. In addition to his consulting practice, Professor Gerwick was for many years on the faculty of the civil engineering department of the University of California at Berkeley.

In 1957-'58, Professor Gerwick served as PCI's fourth president. In recognition of his contributions to the industry, he received PCI's Medal of Honor Award and was also conferred a PCI Honorary Member. Active for many years in the Fédération Internationale de la Précontrainte (FIP), he served as its president from 1974-'78. For his extraordinary services, he was awarded the Freyssinet Medal. An honorary member of several professional societies, he was elected a member of the prestigious National Academy of Engineering in 1980. Professor Gerwick is the author of three books and more than 160 technical papers.

The author discusses worldwide technological advances in precast and prestressed concrete and relates these developments to emerging market opportunities in North America and in other countries.

Today is Columbus Day — the anniversary of Christopher Columbus first setting foot on the Americas. We are celebrating that great adventure of his. Columbus failed in his mission to discover a short route to Cathay, but he did not fall off the edge of the Earth. What he did accomplish was to capture the imagination of Western Civilization by demonstrating that the world is a globe.

Today, 499 years later, we are witnessing the globalization of the world's economies, which has its counterpart in the rapidly increasing interchange of ideas, techniques, opportunities and markets. This exchange occurs in both directions. We, in North America, are fed with both fresh ideas and techniques from Europe and Asia while also experiencing growing competition in our own backyards from well-financed, technically competent foreign companies. Yet, opportunities are also being opened up worldwide for American expertise in manufacturing, management and marketing — areas in which we currently excel.

We are well aware of these developments but we have been slow in reacting to the new realities. Like the European Community (EC), which has taken so long to consummate, we in the United States fail to recognize the dramatic changes in our global system, changes that have recently been made strikingly clear in the political sphere, but which are no less far reaching in the economic sector. For exam-

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ple, the birth of the EC is going to highlight a basic inadequacy in our American system of measures and weights, namely, the failure of industry to convert to the metric SI system of units (Systéme Internationale).

Practically every country in the world has switched to the SI system. Our neighbor to the north, Canada, has made the change. Japan has partially moved from metric to SI, which of course, in practice represents only a shift in decimal point. Unfortunately, the American construction industry, after a half-hearted effort in the 1970s, has abandoned the task. Already, legislation has been introduced in the EC to prohibit imports from countries not using the SI system. There is a real potential for trade barriers to set in, which could exacerbate the discrimination which American engineering and construction firms have previously experienced in Japan.

There are three areas in which the American construction industry has shown particular expertise: technology, management and marketing.

First, the United States excels in pretensioned manufacture of precast concrete products. Our double tees and hollow-core slabs have captured the world market as a structurally effective form. Europe is belatedly recognizing the advantages of our I-girders and bulb-tees in bridge construction. Also, the American version of pretensioned railway ties utilizes only 20 to 50 percent of the labor of many European systems. Our prestressed concrete piles, at least on the West Coast, are now being designed not only to resist seismic-imposed curvatures, but to support the superstructure during an earthquake in ductile frame action.

The Precast/Prestressed Concrete Institute (PCI) has taken the lead in precast concrete building construction by recognizing the critical role of joints and connections in a structure and has developed engineering and quality control standards which ensure proper performance. The work initiated by Armand Gustaferro on fire resistance of prestressed concrete has been largely instrumental in the development of worldwide standard fire resistive ratings.

These are technical accomplishments for which the American precast, prestressed construction industry can feel justifiably proud.

Second, from a management viewpoint, the United States has a unique competence in precast concrete plant design and operation. Europe has largely been captivated by the concept of mechanization and even robots, which when they work, are labor saving. But plants in the commercial market need flexibility. The adaptability of concrete is one of its great assets. America has simplified the process and contributed its own ingenuity in material and production flow.

The third area in which America has excelled is in marketing. We are a market-oriented economy and we have to respond rapidly to the demands of our market in order to stay in business. Contrast this with some production-oriented, centrally controlled economies which set up year-round production of standardized units — or with the philosophy that says, "We will produce our own product efficiently and cheaply: if anyone wants to buy it, they can."

Before moving on, it should be mentioned that there is currently an important multiyear joint research program between the United States and Japan that is partially funded by the PCI. Entitled PRESSS (Precast Seismic Structural Systems), the objectives of the program are to develop effective seismic structural systems for precast concrete buildings and to prepare seismic design recommendations for incorporation into the model building codes.

Let me switch my approach now and examine the opportunities we have to learn from abroad. In a sense, the world can be viewed as a global laboratory for research and development. First, let me address the technical advancements.

- One of these is durability. Considerable attention is being devoted in both Europe and Japan to the production of concrete which will prevent corrosion of the reinforcement due to carbonation and chloride ion penetration. The American Concrete Institute (ACI) is now recognizing the durability issue, although somewhat belatedly. Corrosion is largely a function of the coefficient of permeability. Thus, the European effort concentrates on reducing the coefficient of permeability to 10^{-12} to 10^{-13} m/sec (3.3×10^{-12} to 3.3×10^{-13} ft/sec). Contrast this with our products in the United States which have permeabilities of 10^{-8} to 10^{-10} m/sec (3.3×10^{-8} to 3.3×10^{-10} ft/sec), a factor of 1000 to 100,000 times as large! The achievement of these very impermeable, durable concretes is obtained by using carefully graded mixes of high cleanliness, high range water reducing admixtures, and the addition of microsilica and/or pozzolans to relatively rich cement contents. A secondary benefit of this impermeability for exposed and architectural concrete is the elimination of efflorescence and fungus staining. There are, of course, moderate extra costs for such concrete, but the long-term results are dramatic.

- Another advancement is the use of high yield strength reinforcement [75,000 psi (550 N/mm^2)] as primary reinforcement in conventionally reinforced elements or as secondary reinforcement in prestressed concrete members. In Japan, spiral reinforcement for piles and columns is being applied with yield strengths of up to 150,000 psi (1100 N/mm^2).
- A further advancement is the manufacture of elements to very close tolerances, enabling their assembly with dry joints. The 750,000 tunnel liner segments of the Eurotunnel,

linking France and England under the English Channel, were manufactured to tolerances of curvature of less than 1 mm (1/25 in.) and tolerances in fit of 0.4 mm (1/64 in.). See Figs. 1, 2 and 3.

Japanese hollow-core slabs are manufactured to extremely exacting dimensional tolerances and surface smoothness to enable their use as architectural wall panels.

- Alkali-aggregate reactivity, both short-term and long-term, is an increasing problem worldwide. The United States has coped with this problem by restricting alkalis in the cement and banning the use of aggregates with questionable properties. However, it has been found that many aggregates in Europe and Canada have sufficient reactive constituents that result in long-term problems. In the United Kingdom, delayed alkali reactivity is known as "concrete cancer." Recently, long-term problems have emerged in the United States, and we can expect more of these problems in the future. Historically, the American approach to prevention of alkali-aggregate reaction has been to minimize the alkalis in the cement and the reactive silica in the aggregates. The new European approach is based on the fact that about 4 percent silica is a "pessimum," so by adding silica in the form of pozzolan (fly ash and microsilica), they purposely go well above this pessimum level, to levels of 15 to 20 percent silica. This is a particularly effective approach for products which will be immersed in seawater, such as undersea tunnel liners, where the sodium ion can penetrate over time to furnish a significant source of alkali.
- Efficient methods for recycling of aggregate are being developed on a substantial scale in Europe and extensive testing is being carried out to find the best means for obtaining an acceptable product.
- High strength concrete (high performance concrete) is a field in which American researchers and industry have played an important role in development, yet we still have found only marginal applications for its use in precast concrete products.

Fig. 1. Highly impermeable concrete with a water-cement ratio of 0.32 for Eurotunnel tunnel liners.

Fig. 2. Extremely close tolerances are demanded for tunnel liners.

Fig. 3. Erected tunnel liners, Eurotunnel project.

The global industry is now actively developing its use in precast concrete piling, pressure pipe, tunnel liners, bridge girders, offshore platforms and other applications.

- Some recent advances in reinforcing patterns have been carried out by joint European-American efforts. One of these is the mechanically-headed bar (T-headed bar), developed and tested in the United States, introduced in Canadian codes, and first set up on a production basis by a European manufacturer. It is being widely used in offshore structures and protective structures. The reinforcing bar has excellent potential for use in highly stressed elements, such as the end block of bridge girders, industrial applications and bridge piers.
- Similarly, an anti-bleed admixture, with thixotropic properties, was recently developed in the United States, manufactured by a European company, and first proven in the field as a means of complete filling of post-tensioning ducts back in the United States.
- In the United Kingdom, surface defects, such as bleed holes (bug holes) and air bubbles, are being eliminated by the use of controlled permeability formwork which is affixed to the inside of the forms. This polypropelene fabric is permeable to water, but not cement paste.
- Another area from which we can learn from overseas is in the expanded use of precast concrete members in foundations. In France and Hong Kong, precast concrete slabs are being installed in slurry trenches in order to enable their direct use as walls for subways, underground garages and basements. Precast bearing units are set through slurry in predrilled holes and grouted to form high capacity piers which are reliable in quality and performance. Similarly, precast, pretensioned tie beams are extensively used in seismic areas. The Japanese have developed precast, pretensioned sheet piles with a deep arch section.
- Prestressed concrete poles, both tapered and constant cross section, are used almost universally in every country of the world except the United States and Canada. Even in the forested areas of Europe, trees are considered much too valuable to be used for poles!
- Prestressed concrete railroad ties (or sleepers, as they are called in many parts of the world) are also replacing wood ties in almost every country. They are used on mainline high speed tracks because their stability with welded rails minimizes the ballast maintenance. They are also being utilized for secondary track to reduce the deterioration due to inadequate drainage. An interesting development in China is a wide railroad tie, about 24 in. (610 mm) in width, that is profiled and pretensioned like our standard American ties, but it is used to replace two conventional ties.
- Extensive use is being made in Europe of thin precast conventionally reinforced soffit forms. These stay in place. Their use not only saves the labor of stripping, but shortens the construction schedule. These slabs for bridges and buildings are similar to those we use, except they are often thinner and sometimes ribbed to increase the stiffness. Such

Fig. 4. Precast concrete production plant for King Fahd Causeway Bridges, Saudi Arabia to Bahrain.

slabs, in three-dimensional shell forms, are used in major engineering projects. The shallow domes of the 70 ft (21.3 m) diameter cells of the Norwegian offshore platforms are now formed with two large precast thin shells with edge stiffeners. It is surprising that while these shells are tied to the permanent concrete by mild steel loops, no attempt has yet been made to develop composite behavior in the entire structure.

- Major advances have been made in large scale precast prestressed concrete plants for major projects: The Ju' Aymah Trestle, 20 km (32 miles) in length, and the King Fahd Causeway Bridges, both in the Arabian Gulf, started with the installation of large scale production plants for the voluminous products which were required. Figs. 4 and 5 show the erection of the King Fahd Causeway Bridges. Massive housing projects in Riyadh similarly required a huge production facility.

Fig. 5. Erecting precast concrete segments for the King Fahd Bridges between Saudi Arabia and Bahrain.

Two plants with entirely different production philosophies were set up to produce the 750,000 tunnel liner segments for the Eurotunnel. The French scheme was a highly automated industrial plant, while the British plant employed a very practicable expansion of conventional processes.

Most striking of all is the plant for the Great Belt Western Bridge in Denmark, where several hundred precast concrete segments up to 6000 tons in weight are being manufactured (see Fig. 6). These developments reflect the growing trend toward precast concrete production as opposed to cast-in-place construction. A further motivation is the higher quality demands, especially durability, which cannot be achieved in the field.

- Most European countries and Japan place a far higher value on long life and minimum maintenance than we do here. Design lives of 120 years are now becoming standard. Present value analyses of future expenditure for maintenance, including interruption to service, are being used to justify increased first costs. The extreme example of this is the pier shafts of the Trans-Tokyo Bay Bridge, which have been changed from concrete to titanium-clad steel at a cost of \$40 per sq ft (\$414 per m^2) of surface area for the titanium sheathing alone! Could we not attain equal durability in concrete through the intelligent use of a portion of

Fig. 6. 6000 ton prestressed girder, 104 m (308 ft) span for Great Belt Western Bridge, Denmark.

Fig. 7. Post-tensioned girder for BARTD Metro System, San Francisco, California.

that extra expenditure?

- Another area in which we can and must change is the general aversion which much of our industry has to post-tensioning. I am well aware of the deep split in this country between the precasters and the post-tensioners. (I still bear some of the scars of the early battles!) But that should be in the past. Both groups spend excessive unproductive energy and money in trying to dominate the same market, instead of viewing precasting, pretensioning and post-tensioning as techniques to be utilized by each of us to enlarge the overall market.

Let us now look at how the post-tensioning method is being advantageously used by precasters overseas:

(a) Where the production runs are too short to amortize the cost of set-up of a long-line pretensioning bed.
(b) Where the total prestress force exceeds the capacity of pretensioning beds and stands.
(c) Where biaxial prestress is required in a member or structure.
(d) To provide continuity in a structure.
(e) For curved members and complex shapes.
(f) To join multiple precast concrete elements in structures such as tanks and towers.
(g) To provide transverse compression and stability in bridge decks.

Twenty years ago, Peter Kiewit Son's Co. successfully and profitably manufactured more than 3000 precast, prestressed trapezoidal box girders for the San Francisco BARTD system using post-tensioning (see Fig. 7). Many structural members can advantageously utilize a combination of pretensioning and supplemental post-tensioning, as shown in Fig. 8.

If I were addressing the Post Tensioning Institute (PTI), I would only change this list to include the potential expanded bridge market by the use of higher quality plant manufactured precast segments and those incorporating both architectural treatment and structural capability.

Fig. 8. Elegant and efficient truss of high strength precast concrete segments, joined by post-tensioning.

Concluding Remarks

The globalization of world economies is even now affecting our industry significantly. We have the opportunity to enhance our already brilliant achievements if we stay abreast of the technological advances and product developments which are occurring overseas. In turn, we should take advantage of the opportunity to exploit worldwide those areas in which we are most advanced. We have three self-imposed constraints from which our industry must free itself if it is to prosper and lead the way in the 21st century.

Firstly, we have been too complacent as far as quality is concerned, limiting ourselves to criteria which today can be equally satisfied by cast-in-place concrete. The precast concrete industry's unique advantage lies in our capacity to manufacture economically, well-engineered, state-of-the-art products with superior strength, finish, tolerances and high durability.

Secondly, American industry will have to adopt the international system of units. The precast and prestressed concrete industry should take the lead and at least become literate in SI units so as not to miss global opportunities.

Thirdly, we must increase our versatility by freely using post-tensioning in conjunction with our pretensioning technology.

Lastly, I fervently believe that our industry has not reached its full maturity or potential. Therefore, we cannot afford to remain complacent, static and limited. On the contrary, I feel that the American and world construction industries are on the threshold of a major shift to precast concrete construction which will dominate the early 21st century. This transformation is being accelerated by a general shortage of skilled field construction labor accentuated by demands for better quality, greater efficiency and tighter cost control.

The question is only whether or not our PCI producer members will continue to meet the challenges and opportunities, both technologically and in market expansion, that are being opened up by the worldwide shift to a global economy. In that connection, the 1994 joint congress between the PCI and the Fédération Internationale de la Précontrainte offers a unique opportunity to enlarge our global perspective.

I congratulate PCI on its foresight in deciding five years ago to host this major international event. I believe the congress will prove especially rewarding to our members and our industry at large — leading ultimately to expanded markets and new clients.