The Legacy of the Walnut Lane Memorial Bridge

By George D. Nasser

This article traces the history of the Walnut Lane Memorial Bridge and recounts how this famous prestressed concrete structure transformed the construction industry.

"A theory should be made as simple as possible but not so simple that it does not conform to reality."

– Albert Einstein

The year 2010 will mark the 60th anniversary of the construction of the Walnut Lane Memorial Bridge (1950) in Philadelphia, Pa. It also marks the 20th anniversary of the reconstruction of the superstructure of this bridge. Why is this bridge of such special significance still today? To begin with, it is the first major prestressed concrete structure built in North America. More importantly, the successful completion of the Walnut Lane Memorial Bridge spawned the development of the multi-billion dollar precast/prestressed concrete business that has revolutionized the construction industry.

Prior to the Walnut Lane Memorial Bridge, the only meaningful prestressing activity occurring in the United States was the research and application of pretensioned cylindrical piles in Louisiana and the circumferential post-tensioning of wall panels in water tanks by the Preload Corporation. In addition, consulting engineer Ross Bryan conceived the idea of post-tensioning machine-made concrete block into beams, from which several county bridges were built. But despite all these efforts, their impact on the construction industry paled in comparison to the publicity and excitement generated by the Walnut Lane Memorial Bridge.

The original Walnut Lane Memorial Bridge in Philadelphia's Fairmount Park (1950). The main span is 160 ft (49 m) and the superstructure is about 50 ft (15 m) above Lincoln Drive.

Early Prestressed Concrete

At the outset, it should be emphasized that the Walnut Lane Memorial Bridge was not the first long span prestressed concrete bridge in the world. It is generally recognized that the inventor of prestressed concrete is the Frenchman Eugene Freyssinet. As far back as 1927, as a direct consequence of his observations on the behavior of the great Plougastel concrete arch bridge in France, as well as his other studies, Freyssinet concluded that the idea of prestressed concrete could be made into a practical reality, if high tensile steel could be stressed in combination with high strength concrete. In the next decade (prior to World War II), Freyssinet applied his prestressing ideas in the manufacture of piles and poles, and in the construction of bridges, dams, harbor works, and other diverse types of structures, primarily in France.

Freyssinet was proud to call his invention "an entirely new material possessing properties very different from those of ordinary reinforced concrete." This concept proved to be somewhat controversial, but Freyssinet stuck to his position until the end of his life. Today, in both Europe and North America, reinforced concrete and prestressed concrete are lumped together and called "structural concrete."

In the 1930s, the progress of prestressed concrete was hampered due to the fact that the technology of prestressing steel was not sufficiently developed, i.e., the steel was too brittle and not ductile enough. When prestressing steel was stressed, prestress losses were so high that the prestress force remaining was relatively small and thus did not significantly strengthen the member. Ultimately, the onset of World War II in 1939 put an end to further activity in prestressed concrete.

At the end of World War II, the infrastructure (especially bridges) of Europe was heavily damaged, and therefore needed to be rebuilt. Structural steel was in short supply and hence concrete became a preferred material. With improving technology, the economics favored prestressed concrete and therefore many of the new bridges in Europe were being constructed using this innovative construction method.

Along with Eugene Freyssinet, Professor Gustave Magnel of the University of Ghent, Belgium, was well versed not only in the fundamentals of prestressed concrete but also in the practical design/construction aspects of the material. In addition, unlike Freyssinet, Magnel was fluent in English. At the University of Ghent, Magnel would give his prestressed concrete lectures in three different lan-

Underside view of Walnut Lane Memorial Bridge, showing the 13 post-tensioned concrete girders (1950).

guages, French, English and Flemish. His students revered him so much that frequently some would attend the same lecture twice! Magnel was also a good friend of some of the army veterans returning to Canada from the war. Influential, too, was the support of the Belgian-American Educational Foundation.

The stage was thus ideally set for Magnel to take his lecture tours to Canada and the United States, in which he introduced prestressed concrete to the engineering community. This he did several times starting in 1946. Everywhere he went, he was received enthusiastically and the lecture halls were filled to capacity. His reputation as one of the world's leading authorities on prestressed concrete was becoming apparent.

Innovative Design for a U.S. Project

Meanwhile, plans were proceeding to build a large three-span bridge over Lincoln Drive in beautiful Fairmount Park on the outskirts of Philadelphia. Fairmount Park is no ordinary park. It is one of the largest and most prestigious parks within city limits in the United States. Therefore, any new structure, and especially such a large-scale bridge, would have to go through a very rigid approval process by Philadelphia's Bureau of Engineering, Surveys and Zoning, as well as Philadelphia's Art Commission.

In a bridge design competition, several imaginative design proposals were submitted. After intense negotiation, the design proposal submitted by the Preload Corporation was accepted. A key ingredient in the proposal was the innovative prestressed concrete bridge design which the company had secured from Gustave Magnel. In the final contract, there was a clause stipulating the testing to destruction of a full-sized main span girder of 160 feet (49 meters) at the bridge site.

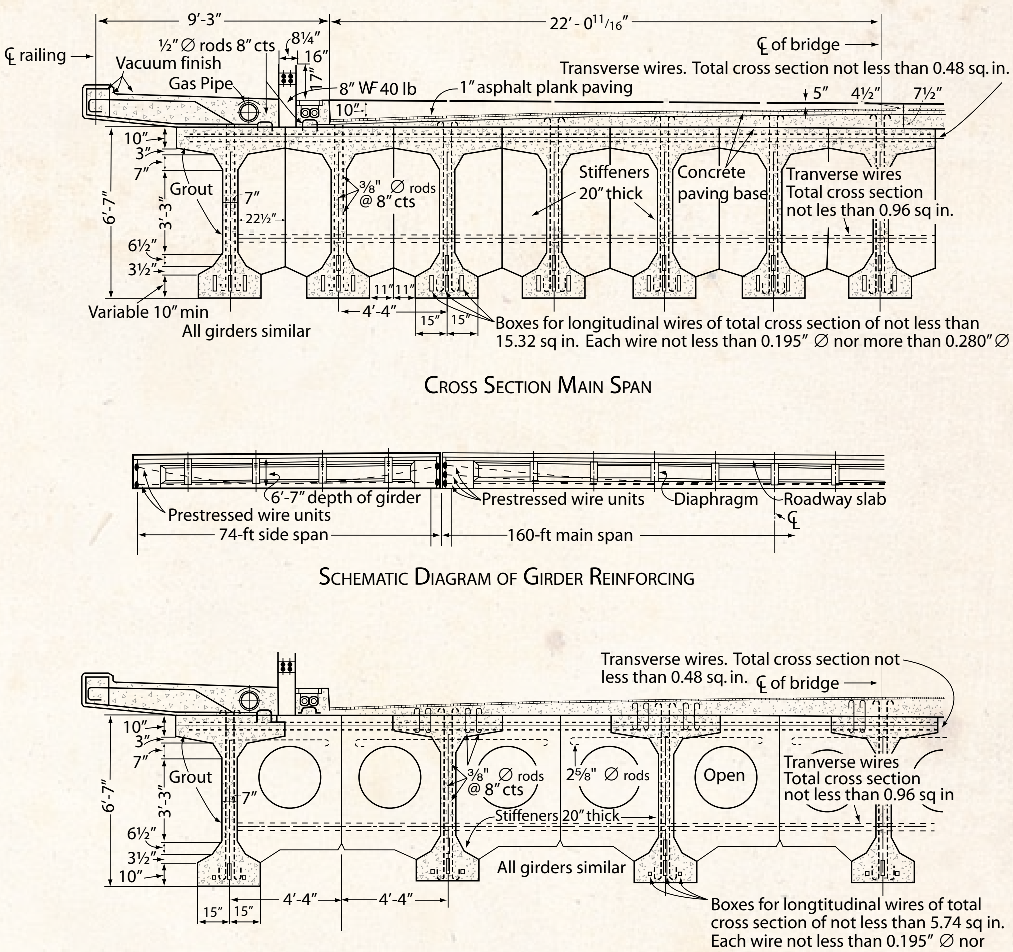
In retrospect, despite Magnel's brilliant design scheme, it still took considerable courage and vision by Philadelphia's city fathers and building officials to approve such a bold initiative. For example:

- Prestressing had never before been attempted on such a grand scale in North America.
- The main span of 160 feet (49 meters) was fairly long, even by today's standards.
- There were no American building code provisions or specifications in place and, for the most part, European technology and specifications had to be imported.
- Since Magnel resided in Belgium, much of the logistics and communications had to be done across the Atlantic Ocean.

One very fortunate coincidence occurred in that a very knowledgeable structural engineer, Charles Zollman, had earlier joined the Preload Corporation. It so happened that Zollman had been a former student of Magnel at the University of Ghent and over the years had kept in touch with the professor. This relationship proved to be invaluable, and Zollman quickly became the principal American representative in dealing with Magnel and was responsible for the final drawings and supervision of the project.

After several months of intense work, a complete set of construction drawings and specifications in accordance with American practice were finished. By late summer of 1948, the City of Philadelphia's contract drawings were completed. Instrumental in getting the drawings completed was Ted Gutt, the chief draftsman of Preload Corporation. Gutt later became one of the pioneers of the early precast, prestressed concrete industry, and served as chairman of PCI.

A contract was finally awarded in the spring of 1949 to the Henry W. Horst Company for the construction of the bridge, in the amount of $750,000 (1950s dollar values, of course). The Preload Corporation was



Cross sections of the main and end spans of the Walnut Lane Memorial Bridge (1950).

A year before Gustave Magnel's death (1955), the professor (center) admires the Walnut Lane Memorial Bridge with Charles Zollman (left) his former student and good friend and Samuel Baxter (right) representing the American Society of Civil Engineers.

awarded the subcontract to fabricate the prestressed concrete girders. Magnel was responsible for the conceptual and final design of the bridge, and also served as construction advisor.

Testing and Construction

Testing of the 160-foot (49-meter) long and 6-foot 7-inch (2-meter) deep girder, identical to the girders forming the center span of the bridge, was conducted on October 25, 1949 adjacent to the site of the bridge. The test demonstration attracted some 300 engineers, building officials, as well as representatives from the news media, from seventeen states and five countries, all of whom stood in the rain for the entire day to witness the unfolding drama.

Magnel himself supervised the test demonstration and provided the audience with a running commentary on the progress of the test. To the astonishment of some skeptics, Magnel correctly predicted the behavior of the girder during each loading phase and foretold the favorable outcome of the load test. The girder testing was completed with satisfaction, thus leading to the actual construction of the bridge.

It is interesting to note that the instrumentation of the prototype testing was done by Dr. Arthur Anderson. He later founded ABAM Engineers and Concrete Technology Corporation, and was a pioneer of the early precast, prestressed concrete industry, including serving as chairman of PCI.

The Walnut Lane Memorial Bridge is a three-span structure with a central span of 160 feet (49 meters) and two end spans of 74 feet (22.5 meters). The superstructure is supported on two four-column abutments 50 feet (15 meters) high above Lincoln Drive. The roadway is 44 feet (23 meters) wide. The bridge was designed as a post-tensioned, precast on site structure.

The central span of the original superstructure comprised thirteen 79-inch (2-meter) deep concrete I-girders that were post-tensioned both longitudinally and transversely. Each girder weighed 80 tons (73 tonnes). In the longitudinal direction, each girder required 256 high strength, stress-relieved single wires having a 0.276-inch (7-millimeter) diameter.

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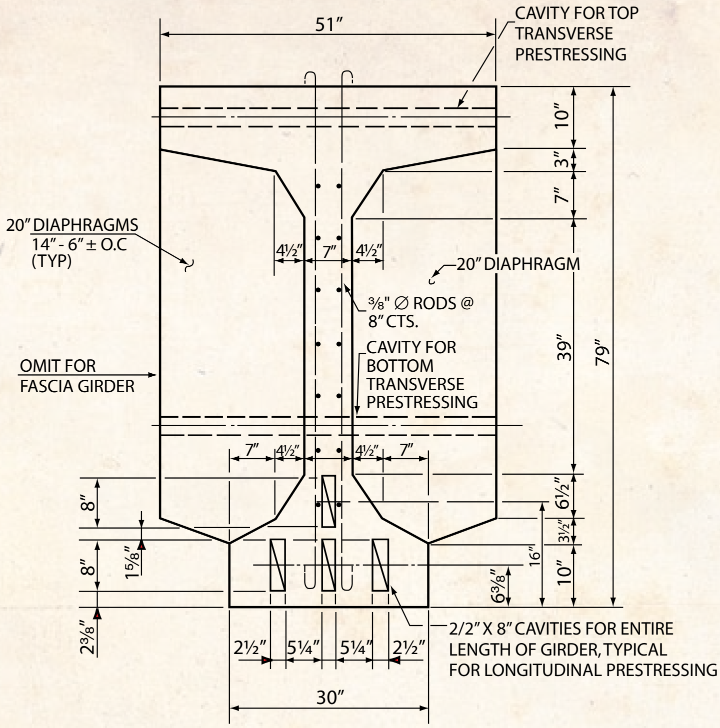


Midspan cross section of typical main span girder (1950).

In each girder, the 256 wires were placed in four rectangular ducts, each receiving 64 wires. Longitudinally, the two outer ducts in the bottom flange remained straight throughout the span while the ducts in the web were curved up at the ends to create a parabolic shape.

In the end span, only three ducts were required. Each of the outer ducts housed 24 wires, which remained straight throughout the span. The center span, housing 48 wires, curved up parabolically. The wires were stressed to produce a total initial force of about 750,000 pounds (3.3 MN) per girder. The girders were also post-tensioned transversely at the top flange and web of each girder at several locations along the main span.

All prestressing wires were anchored in pairs using the Belgian Magnel-Blaton system. The anchorage consisted of steel plates, called sandwich plates, with two trapezoidal grooves in the upper surface and two in the lower surface. A machined steel wedge fitted into each slot and fixed two wires in each groove. To protect the wires from corrosion, a conventional grout was injected into the ducts.

Construction of the bridge proceeded smoothly and was opened to traffic in late 1950.

It is interesting to note that the stress-relieved wires were developed by the John A. Roebling Company, an American invention. This development was an improvement over European prestressing steels. Roebling, who much earlier had supplied the wire rope for the famous Brooklyn Bridge, had also developed seven-wire strand but Magnel felt that this strand had not been sufficiently field tested. Of course, today, the industry in the United States and around the world almost universally uses low-relaxation ½-inch (13-millimeter) diameter seven-wire strand.

The Beginning of an Industry

What were the repercussions following the successful completion of the Walnut Lane Memorial Bridge? First, it inspired the creation of a new industry, namely, the precast/prestressed concrete industry. Similar to Europe after World War II, there was a shortage of structural steel in North America, which made concrete, and particularly prestressed concrete, an attractive alternative material.

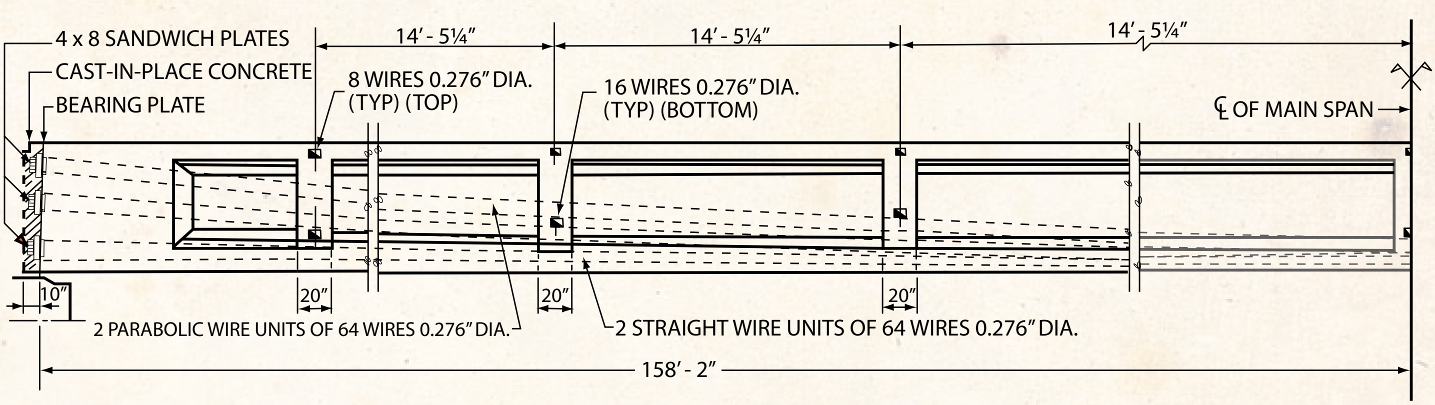
The direction the new technology would take in the early 1950s was influenced by several developments. Large-scale prefabrication using prestressing techniques provided the impetus for the establishment of precasting plants across the United States. Key in this was the development of seven-wire prestressing strand and long-line stressing beds for the production of standardized precast/prestressed concrete members. By employing new precasting techniques, prestressing operations could be made more efficient and economical.

The possibilities for prefabrication were vividly demonstrated with the construction of the 24-mile long (39 kilometer) Lake Pontchartrain Causeway (1955-1956) near New Orleans, La., which at the time was the longest precast, prestressed concrete bridge crossing in the world.

Another influential development in the expansion of the precast concrete industry was the inauguration of the federally aided Interstate Highway Program in 1956. This highway system, together with the network of roads built around it, soon proved vital to the safe and economical transportation of precast concrete products to project sites.

In the beginning (early fifties), the precasting plants were mostly in Florida because of the moderate climate, but later they spread all across North America. Today, there are more than 300 plants in the United States belonging to some 150 producer companies.

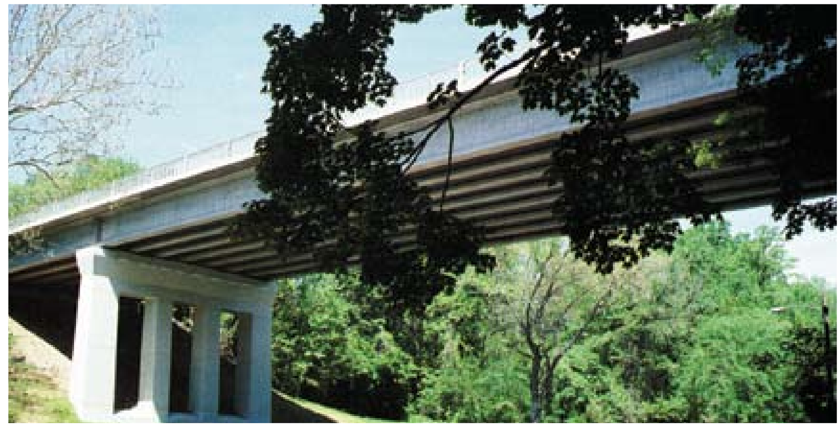
At first the new prestressing techniques were only applied to bridge applications, but enterprising engineers and contractors quickly realized that the same technology could also be applied to buildings and other structures. The introduction of the double tee and hollow-core slab were of paramount importance in the building field. Today, more than 70 percent of bridges in the United States



Profile of longitudinal wire units in the main span girder of the bridge and the location of the transverse prestressing wire units (1950).

are constructed of prestressed concrete, most of which use standardized precast, pretensioned members. Similarly, at least 70 percent of parking structures are built using precast/prestressed concrete. A few years ago, a 39-story total precast, prestressed concrete building was built in San Francisco, one of the most seismically active regions in the world. Also, many prominent high rise buildings in North America are now clad with architectural precast concrete.

A natural evolution of the early prestressing activities nationwide is that the Prestressed Concrete Institute (PCI) was established in Tampa, Fla., on June18, 1954. One major outcome of this event is that, as a national organization, the PCI was able to influence the formulation of code provisions for prestressed concrete. Note that in 1959 PCI moved its headquarters to Chicago, Ill., and in 1989 modified its official name to Precast/Prestressed Concrete Institute.



View of the new Walnut Lane Memorial Bridge completed in 1990.

Conclusion

The original Walnut Lane Memorial Bridge provided excellent uninterrupted service for nearly 40 years. Then in 1989, some longitudinal cracks appeared in each of the fascia girders. Although the condition of the interior girders were mostly normal, it was decided to replace the entire superstructure. This decision was controversial but there was some vindication in that the method of replacement was the selection of precast modified AASHTO I-girders. It must be appreciated that the state-of-the-art of prestressed concrete had advanced considerably over 40 years and is continuing to progress to this day.

The history of the Walnut Lane Memorial Bridge ends with the fact that while the original bridge was basically a post-tensioned concrete bridge, the new superstructure is a precast, pretensioned concrete structure. The new superstructure has been performing excellently during the past 20 years. In a special ceremony in 1977, the original bridge was designated by the American Society of Civil Engineers as an "Outstanding Civil Engineering Achievement."▪

George Nasser is editor emeritus of the PCI Journal. A well-respected authority in the precast concrete industry, he was editor-in-chief of the PCI Journal for more than 30 years. He is a PCI Fellow and was named a Titan of the Industry in 2004.

For further information on the Walnut Lane Memorial Bridge, a list of references is provided in the online version of this article. Visit www.STRUCTUREmag.org.

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