Reflections on the Beginnings of Prestressed Concrete in America

Nineteen seventy-nine will be the 25-year Silver Jubilee of the founding of the Prestressed Concrete Institute.

To commemmorate this important anniversary, the PCI JOURNAL is presenting a series of papers on the early history (based on personal experiences and recollections) of prestressed and precast concrete in North America. These papers will be narrated by the persons who participated in the early development of the industry.

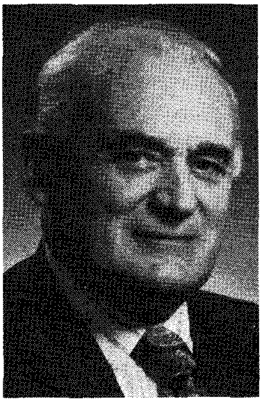
Part 1 (appearing in this issue) traces the events that led to the construction of the Walnut Lane Bridge. Particular emphasis is given to the significant role that Professor Gustave Magnel played in introducing prestressed concrete to America.

Succeeding papers will deal with subsequent events and developments which had an important effect on the early growth of the prestressed concrete industry in America.

We believe that these series of articles will not only be fascinating to read but will serve as a historical record of one of the most exciting periods in the annals of construction.

Part 1

Magnel's impact on the advent of prestressed concrete



Charles C. Zollman
Director of Engineering
Urban Engineers of Maryland, Inc.

Whatsoever a man soweth,
that shall he also reap
(Galatians 6:7)

No single event was more instrumental in launching the prestressed and precast concrete industry in North America than the construction of the Walnut Lane Bridge in Philadelphia in 1950 (see articles in Sept.-Oct. 1976 PCI JOURNAL[1]).*

More than anything else, however, it was the charisma, dynamism, and engineering talent displayed by the man who designed the Walnut Lane Bridge, namely Professor Gustave Magnel of Belgium, that gave the impetus necessary for the acceptance and development of prestressed concrete in the United States.

On the other hand, very few know *how* this came about, *how* the Belgian-American Educational Foundation, an American-sponsored organization founded in 1920 as an aftermath of World War I, was to be instrumental in bringing Professor Magnel to the United States in 1946. Nor is it known how many apparently unconnected events and coincidences which took place during that period, led to the construction of the Walnut Lane Bridge.

This is an extraordinary and fascinating story which I believe should be recorded for posterity.

*It should be mentioned that the principles of prestressing had been known and applied to circular tanks much earlier in North America.

The author traces the events that led to the construction of the Walnut Lane Bridge—the first major linear prestressed concrete structure in the United States. In particular, he emphasizes the significant role that Professor Gustave Magnel played in introducing prestressed concrete to North America.

Belgian-American Educational Foundation

America's compassion for the downtrodden and its generosity towards them is legendary. During World War I, it was exemplified by the activities of the "Commission for Relief in Belgium" chaired by Herbert Hoover, who later became the 31st President of the United States.

At the end of World War I, the Commission was left with a substantial surplus of funds. Herbert Hoover, who had become fond of the Belgians, was convinced it was in the best interests of Belgium and the United States, to continue this assistance, though in another form. He then founded the "Belgian-American Educational Foundation" to be funded from the "Belgium Relief" surplus. The Foundation's purpose was to select about 15 to 20 of the most promising graduates in any field or discipline from the four Belgian-Government sponsored Universities: Ghent, Brussels, Louvain and Liege.

Each year, beginning in 1920, graduates in law, medicine, engineering, the sciences, music, business administration, and in many other disciplines were invited for a 1-year stay in the United States. They were encouraged to pursue an education at an American university of their choice. No strings were attached to this invitation* although it was understood that at the end of their studies they would return to Belgium with the expertise and singular "know-how" acquired in the United States.

At the time, Herbert Hoover did not realize the extent of the impact the Foundation would have on American-Belgian political and economical relations. To some degree, this relationship would affect the outcome of World War II and the introduction of prestressed concrete to the United States. Thus, until 1940 when the Germans invaded Belgium, temporarily halting the Foundation's activities, Belgian graduates annually came to the United States. Most of them acquired advanced degrees, usually doctoral degrees.

By 1940, many of the Foundation's alumni had become leaders in Belgium's industry, business and government. Some were instrumental in developing business with the United States, others became influential in Belgian politics, or other national and international bodies. For example, Armand Cerulus, a student of Harvard's extraordinary Professor

*For the record, the Foundation's original name during the Hoover Administration was "C.R.B. Educational Foundation." Essentially, the Foundation's policy arranged for the exchange of students between Belgium and America; American graduates also attended Belgian universities in a 1-year annual exchange.

The Author

Charles C. Zollman was instrumental in the promotion, development, design and construction of Philadelphia's Walnut Lane Bridge, the first major prestressed concrete bridge in North America. He was the first chairman of PCI's Technical Activities Committee from 1957 to 1960 and an active participant in PCI affairs as director from 1956 to 1959.

Mr. Zollman's early consulting services for the design and construction of pretensioning plants throughout the United States, his activities in the field of precast concrete as well as his many contributions to the PCI, have identified him as a pioneer of this industry in North America.

Mr. Zollman was a student of Professor Gustave Magnel at Ghent University, Belgium. Later, he became Magnel's unofficial representative in the United States, responsible for the detailed arrangements of Magnel's several trips to this continent.

In 1973, the Delaware County Chapter of the Pennsylvania Society of Professional Engineers named Mr. Zollman "Engineer of the Year." The honor was bestowed for his "Engineering Excellence in the design and administration of numerous large civil engineering projects; for his pioneering achievements in the design of prestressed concrete bridges and for his dedication as a teacher of the theory of prestressed concrete design."

Filmore Swain, later became full Professor of Architecture at Ghent University. Leon Rucquoi eventually became the Technical Consultant in New York for the Steelmakers and the Metal Working Industries of Belgium and Luxembourg. Fernand Chenu was made head of the Electrorail empire which merged with Westinghouse after World War II. Daniel Vandepitte, who designed and supervised the construction of Belgium's first suspension bridge using prestressed concrete stiffening girders, was later appointed Professor and Rector (President) of Ghent University. There were many others.

During World War II, when available minerals such as nickel, cobalt, tin, zinc and radium were unavailable to the Western Allies, some of the Foundation alumni (who had escaped to England) helped America obtain these scarce materials from the Belgian Congo (today known as Zaire). The shoe was on the other foot and this time the Belgians were on the giving end.

This explains why Belgium was the only country in the world not financially obligated to the U.S. after World War II. The U.S. owed the Belgian Government substantial amounts of money for goods received during the war years. This unusual situation was one factor which enabled Belgians to rapidly get reestablished. Belgium's speedy recovery and the hard work of the Belgians helped make Brussels (Belgium's capital) the first European Market capital. Belgium also became headquarters for NATO.

As the years went by, other international organizations, American businesses and industrial enterprises selected Belgium as their headquarters. Unobtrusively, the Foundation did its share in furthering Belgium's interests.

Since all of the Foundation's activities were halted by World War II, funds had accumulated. These surplus funds made it possible to extend the Foundation's exchange, after the war, to representatives of Belgian business, enterprise and industry. They were invited by the Foundation to spend 1 to 3 months studying American technology which had developed substantially during the war years.

Magnel's Influence

Gustave Magnel, Professor of Engineering at the University of Ghent, was chosen to represent the entire Belgian construction industry as well as Belgium's educational and technical professions. From April to June 1946, Magnel toured the United States as "Belgian American Educational Foundation (BAEF) Scientist" and as a "member of the Belgian Scientific Mission to the United States."

Teacher Par Excellence

As early as the late twenties, Magnel's eminence as a teacher was known worldwide. The student body at the University of Ghent was a miniature "United Nations." Students flocked to Ghent to attend his structural engineering and reinforced concrete classes. His ability to present in clear and simple language the most complex theories and problems was unique and unparalleled.

Magnel was fluent in English, French and Flemish. He taught in the latter two languages with equal facility, without a trace of an accent. Students would never cut his 90-minute classes. On the contrary, they would attend classes in both languages, even though some students may have been fluent in only one language.

I remember, after nearly 40 years, my first class with Magnel. As the mild-mannered, soft spoken man walked into the room, all would stand in deference, respect, even awe. He'd gesture for us to sit down, then he'd put on his "pince-nez," look us over quietly, a grin would appear . . . and then he'd begin:

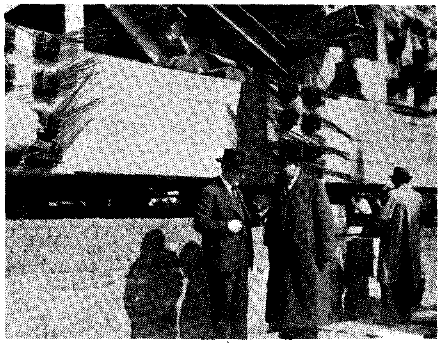


Fig. 1. Professor Gustave Magnel (left) at job-site inspecting underpinning of tower.

> "Gentlemen, you have now been with this University for 2 years. You must, by now, be excellent mathematicians. But do not expect me to fill this large blackboard with all kinds of complicated formulas and their derivations. It is true that I would look like a very learned man—but that is not why I am here. I must make engineers out of you—in less than 2 years—so that you can design and analyze structures rapidly and as accurately as possible—not mathematicians who will need 6 months to solve a problem based on assumptions . . . which are inaccurate anyway. By that time the building would have been constructed by someone else."

Magnel essentially was practical as a result of his great wealth of experience (Fig. 1). Always methodical, efficient, and down to earth, he also brought a rare degree of human sympathy and insight to his relationships with his students. And they in turn revered him.

Patriot Par Excellence

It is no wonder that the Germans upon occupying Ghent in 1940 immediately removed Magnel from the University to eliminate his influence. They still allowed him to remain as Director of the Reinforced Concrete Laboratory (now bearing his name) which he had founded in 1926. It originally was located in the basement of a former hotel and later

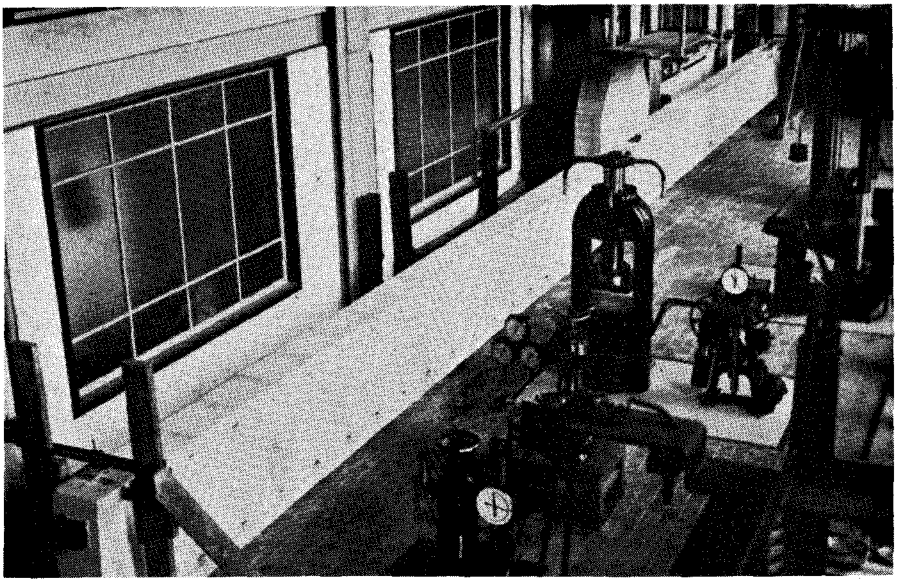


Fig. 2. Magnel's Reinforced Concrete Laboratory tested only full-scale concrete members. Magnel had little use for small-scale models. Shown here is the testing of a 66 ft (20 m) block beam.

moved to expanded laboratory facilities, and modern quarters. By 1940, it had become the most advanced and sophisticated research and testing laboratory for reinforced concrete in Europe. His great pride was the office overlooking a portion of his laboratory (similar to a captain's ship-bridge) where he would observe the testing of *full-sized* concrete members. Magnel had little use for tests on small-scale models (Figs. 2 and 3).

During the German occupation, Magnel was deeply concerned for the fate awaiting his young engineering graduates. He remembered World War I when such men were sent to work in Germany for the enemy. He undertook the task of trying to keep these young men in Belgium. No doubt, because of his unusual personality, he managed to foil the Germans' plans convincing them it was to their benefit for this man-power to stay in Belgium working on a new development. That development, of course, was prestressed concrete!

It should be noted here that the Germans favored pretensioning as can be testified by its use in the construction of submarine bases along the Atlantic and North Sea coast. American research teams sent to Germany and the occupied countries immediately after World War II have assembled data on this particular German war activity.

During these secluded years at the laboratory, Magnel had the opportunity to conduct full-scale research on prestressed concrete, including investigations on the phenomena of creep of steel and shrinkage of concrete, buckling and other problems. He also developed his post-tensioning system including the anchorages later to be known as the "Belgian or Magnel-Blaton prestressing system and sandwich plate anchorages." In doing so, he managed to keep the young Belgian engineers from having to work for the Germans.

When Magnel later tested the concrete "poured" at the Atlantic Wall along the North Sea coast, the test cubes (equivalent to American test cylinders)

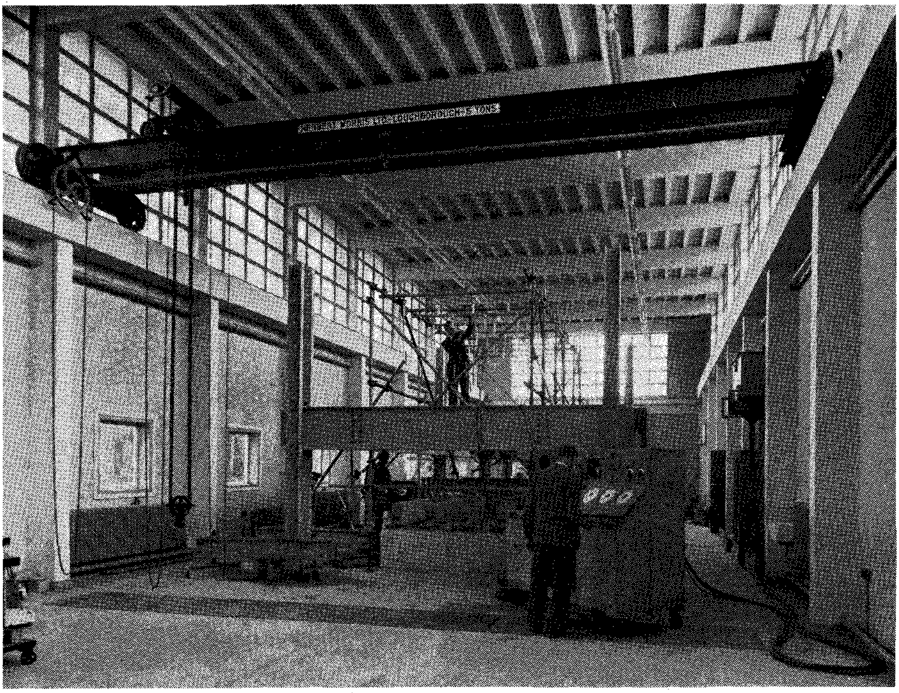


Fig. 3. General view of the interior of the structures' laboratory showing the test frame with bridge decks in position for testing. The hydraulic console is shown in the foreground.

showed, invariably, to be of low strength resulting in dire consequences for German field personnel!*

At this point, the Nazis suspected Magnel and during 1944 Gestapo orders were issued for his arrest and deportation to Germany. Luckily, Magnel was not in Ghent the day the Gestapo looked for him; his secretary had managed to hide him in Brussels. He remained a fugitive until the end of the war. He stayed constantly on the move and did not sleep in the same place more than one night. The Nazis never caught him.

With the British and Canadian Armies advancing, the Germans retreated from Belgium. Soom after, Magnel repossessed his teaching chair at the University.

There is an ironic personal note to the story of Magnel's teaching chair at the University of Ghent. His pre-war laboratory assistant was a former student whose education had been subsidized by Magnel. During the war, this student collaborated with the Germans and temporarily seized Magnel's "chair." When Magnel rightfully regained his seat, the former assistant fled Belgium and was never heard from again.

As far as Magnel was involved, the ultimate blow to the Germans' military strength came when Brigadier Jean Paul Carriere† of the Canadian Army requested Magnel's assistance. A canal crossing in Ghent was urgently needed to carry fuel lines. With an enigmatic smile, Magnel promised to construct the

*Legend has it that he deceived the Germans in many other ways, but Magnel in his modesty rarely talked about it. For example, the story goes that some of his sophisticated, in-house designed testing instruments with their many dials, were in reality radio transmitters to London!

†Brigadier Jean Paul Carriere was later to become President of Franki Canada Ltd.

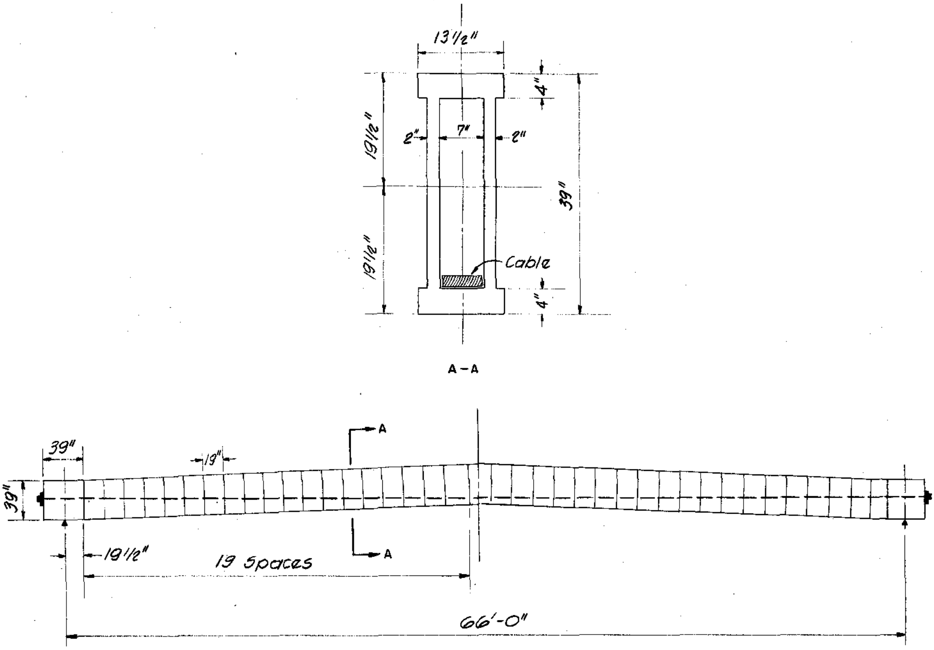


Fig. 4. Block beam used by Canadian Royal Engineers to carry British fuel lines at Ghent crossing, Terneuzen Canal, in 1944.

indispensable bridge in only *one day.*

He made this commitment with solid confidence. Long before he had gone into hiding, the Germans had ordered him to cast concrete blocks, at their expense, for their buildings. However, Magnel successfully delayed delivery of the blocks on one pretext or another. As he described in his book, *Prestressed Concrete*[2] (see Fig. 4), ". . . and in 1944, the Canadian Royal Engineers used similar beams for a bridge to carry pipelines over the Terneuzen Canal; in this case, the contractor had the beams in stock."

Now, he simply shipped the blocks to the site of the canal crossing, assembling, post-tensioning and erecting a bridge ready to carry the British fuel lines, with remarkable speed.

Magnel took great delight in telling this particular story; he had deceived the enemy once more where they were most vulnerable. Brigadier Carriere and Magnel became great friends, which was an additional incentive for Magnel's several trips to this hemisphere, especially his visits to Canada.

In 1954, Magnel graciously accepted the opportunity to lecture at the Canadian Conference on Prestressed Concrete in Toronto, Ontario. He was instrumental in spearheading the dramatic beginning of prestressed concrete in Canada and the United States.

Introduction of Prestressed Concrete

Meanwhile, I had managed to escape Europe in 1941 and come to the United States where I worked on the East Coast for various consulting and contracting firms. Primarily, I worked as a designer and detailer of reinforced concrete structures.

Between 1944 and 1945, news bulletins issued by the Belgian Consulate in New York sometimes carried items about Professor Magnel: first, that he had disappeared, then, that he had escaped from the Germans and finally, that he had been reinstated as Professor at the University of Ghent.

Learning of Magnel's safety during the summer of 1945, I wrote a congratulatory letter to him. In his handwritten reply, Professor Magnel wrote (among other things), ". . . and I even built and tested a 20 meter (about 66 ft) span prestressed beam,"—which he considered a great achievement in its time. Shortly afterward, Magnel announced that he would visit the United States as an "Advanced Fellow" of the Belgian-American Educational Foundation in spring 1946.

I promptly wrote a letter to Professor Magnel suggesting universities he should visit, consulting engineers to meet, and construction sites to be inspected. I also made arrangements for Magnel to lecture on prestressed concrete, a subject almost unknown in the United States at that time. Indeed, the only information on prestressed concrete published in an American textbook was almost an afterthought. Professor Clarence W. Dunham's book, *The Theory and Practice of Reinforced Concrete*[3] included a chapter titled "Practical Details and Miscellaneous Data." (This book was considered the most advanced and popular treatise on concrete design available at the time.)

Magnel finally arrived in New York City in April 1946. He was greeted by his former secretary (who had saved his life during the Nazi occupation and later fled to the United States) and me. What an emotional reunion this was: the old professor and the young engineer who would be his guide in the New World. So much had happened since my graduation from the University of Ghent in 1939, the last time we met.

Fig. 5. Professor Magnel, the lecturer, on his American tour.

Everything went smoothly during Magnel's first trip to the United States. Because of his easy and outgoing manner and his willingness to listen, he was well received everywhere and accomplished what he came for, namely the study of American developments in education, engineering and construction which had grown enormously during the war years.

Invariably, Magnel would conclude a meeting by saying: "You are so kind to tell me what *you* have done, may I then tell you what *I* have done? I have developed prestressed concrete . . ." and off he went! Fig. 5 shows Professor Magnel addressing one such meeting.

Ammann, the engineer who conceived, designed and who was responsible for the construction of the George

Washington bridge in New York was fascinated by Professor Magnel and discussed at great length the advantages and limitations of oil tempered wires and cold drawn wires. MacLeod, the chief engineer of Corbetta Construction Company, at first reluctantly, then enthusiastically took Magnel to the construction sites of concrete arches around New York discussing with the practical professor his construction problems and what prestressed concrete could do for him.

Although English was not his native tongue, Magnel spoke the language very eloquently (Figs. 5 and 6) and had the rare gift of being able to simplify complex theories and difficult problems.

On his American lecture tours, he captivated large audiences at Columbia University in New York, the Engineers Club in Baltimore, the University of Illinois in Urbana, and many other engineering groups. Throughout America, he described his prestressed concrete work, enunciating his theories and showing numerous, detailed slides. The March 1947 issue of the *Journal of the Engineering Institute of Canada*[4,5] clearly says:

> "This paper is a resumé of several addresses given by the author (Gustave Magnel) before various Branches of the Engineering Institute of Canada in May 1946, and has been prepared for the *Journal* by special request. *Prestressing is explained in a way that any member of the profession could understand* (Fig. 7). Three methods of prestressing are given and each explained in detail. The economies obtainable by the use of prestressing are given and each explained in detail. The economies obtainable by the use of prestressing make this *short and very clear explanation* a subject of prime interest and importance of today's and tomorrow's engineers."* (Italics are added for emphasis.)

*Also see Reference 4 and the Editor's note in the July-August 1954 issue of *Military Engineer*.

Fig. 6. Professor Magnel teaching prestressed concrete.

Two significant events occurred during Magnel's first visit to America which had a direct bearing on the development of prestressed concrete in this country and which culminated in the realization of Philadelphia's Walnut Lane Bridge.

The first event was my introduction of Magnel to the Preload Corporation of New York. At the time, this company was the American leader in the design and construction of circular prestressed structures such as tanks, reservoirs and domes. The Preload Corporation eventually became a sub-contractor for the construction of the Walnut Lane Bridge girders.

Magnel's Book

I believe the most significant effect on the development of linear prestressed concrete in America took place the day before Magnel returned to Europe in 1946. He greeted me in his New York hotel room with the following message: "Before I return to Belgium, I will leave with you the last three copies of a manuscript I have written in French. It is the first comprehensive design and analysis text for prestressed concrete members anyone has ever written. Let me explain it to you . . ." For the next couple of

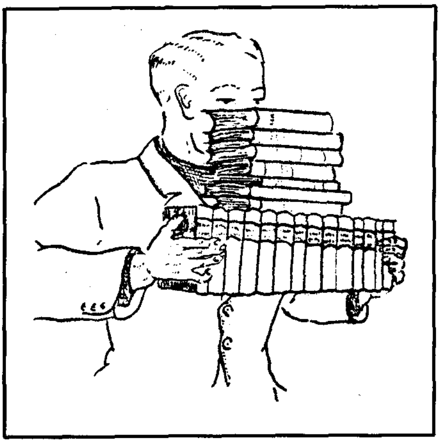


Fig. 7. Professor Magnel's explanation of the principle of prestressing.

hours the Professor proceeded to teach me the fundamentals of the design and analysis of prestressed concrete.

I became so captivated with the clarity and simplicity of Magnel's explanation that I requested permission to translate the manuscript into English for possible publication in an American technical journal. Permission was granted.

However, by the time the translation was submitted several months later, Magnel advised me that he had written a second chapter. Later, there was a third and a fourth chapter, in all, eleven chapters were translated. I could barely keep up with the Professor; no sooner had the translation of one chapter been completed when the Professor had produced the next.

The original manuscript was now sufficiently developed to merit publication as a book: the English version of the French *Le Béton Précontraint.*

Indeed, it was a labor of love. For more than a year, the midnight oil burned. Not only did the text require translation but all drawings, charts, diagrams and tables had to be converted to American measurements. At the time, I could ill afford to have someone else redraw them.

In addition, the nomenclature had to be modified to American standards. All the examples worked out in the metric system were recomputed to the inch/pound system. The rewards of a job well done were immeasurable if not monetarily so. However, the disappointment was painful when American publishers such as McGraw-Hill, Inc. and John Wiley & Sons turned the book down because they could not as yet see a market for the product.

Concrete Publications Limited of London, however, grabbed the manuscript, retranslated it from "American-English" to "British-English," reworked the nomenclature to conform to British practice and published a first edition of 6000 copies in 1948[2] (see Fig. 8).

The book promptly sold out. Eight

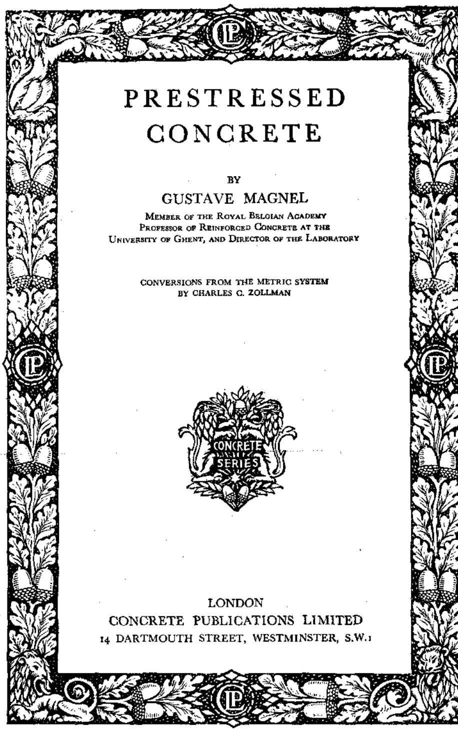


Fig. 8. The first edition jacket of Professor Magnel's book in English on "Prestressed Concrete."

Gustave Magnel

Philosopher • Teacher • Builder
(1889-1955)

People who personally knew Professor Gustave Magnel or were present at his lectures all readily agree on one thing about the man—that he was one of the most effective teachers of his time. Here in slightly edited form are excerpts from some of his more memorable lectures:

• **On complicated formulas**—When I first gave lectures, I used to cover the blackboard with complicated formulas—not on such a tiny one as this but on a big blackboard which has several sections such as are found in the lecture rooms of the Belgian University. I was so proud of myself because I thought I was very clever. But now, since I am older, I have understood that writing complicated formulas does not solve any problems.

• **In explaining the action of prestressing in a statically determinate beam**—Take the simple case of a beam resting on two supports. If we apply a prestress force at the ends of the beam we notice that the beam *cambers* upwards due to the prestressing moment (prestress force times its eccentricity). At the completion of prestressing, the beam still rests on the two end supports. What are the reactions on those two end supports? Well, if everything is symmetrical, the reaction at each support is equal to one-half the weight of the beam. What else could it be? And whether we apply a very large prestress force or a small prestress, each reaction is always equal to one-half the weight of the beam. It is statically determinate.

• **In explaining continuity in a prestressed beam**—Let us now consider a continuous beam having two equal spans. We prestress the beam with wires going from one end to the other. Assume for the time being that the central support is missing—the beam would also curve upward like the simply supported beam. But the central support is there and it says to the beam, "Hey, my little beam, please you may not lift up, I'm keeping *you down*." In other words, the support can only keep that beam down by exerting an external force, i.e., an anchorage force downward—and that is only possible due to simple statics, if we have at each of the outside supports an upward reaction equal to one-half of the anchorage force. With these new forces acting on the beam, we have a new kind of bending moment diagram. In fact, it means that we get so-called "secondary moments" in the beam. These secondary moments are great or small, positive or negative depending on the magnitude and shape of the stressed cable and the cross section of the beam.

• **On Hooke's Law**—We need to develop a reliable theory with which to proportion and reinforce a beam based on its moment of rupture. Unfortunately, in a real case we can no longer apply the laws of elasticity. Don't forget that a design based on a calculation of stresses is nothing more than the development of the assumption that Hooke's Law is applicable, i.e., that stress is linearly proportional to strain ($\sigma = E\epsilon$). Hooke's Law happens to be the only thing that civil engineers know

for sure in their calculations—but it happens to be wrong for most materials. Yes indeed, engineers don't know anything else—sure enough they modify it, they call it the Theorem of Three Moments, Theory of Least Work, and Formulas for Bending and Torsion. But it is always Hooke's Law written in red or green, English, German or Chinese—and it is wrong most of the time!

• **On safety factors**—Everybody loves to talk about safety factors but nothing is more complicated or confusing. It is meaningless to talk about safety factors unless you explain what it is related to for a particular case. (Does it, for example, relate to cracking, breaking or fatigue strength?) To just say that you have a safety factor of 2, 2.5, 2.7, or 3 has no meaning. That depends more on one's bank account! Ja, if you can afford to spend a lot of money—if you are, say, the president of General Motors or somebody like that, you see it doesn't matter how strong you make the beam—you can afford to have a safety factor of 3 or more. However, if you have a very tight budget, you will probably use a safety factor of 2 (but it must be at least 2).

• **On a lecturer's role**—Why are we here together? It is to learn something from one another. If I say "Yes" to everything you believe, then there is no reason for my being here.

• **On corrosion of prestressing steel**—Beware of corrosion! Remember that when wires are placed in a duct they are in a wet, moist atmosphere and in contact with the air. The wires must be surrounded with grout and must never touch one another.

• **On the true behavior of a member**—There is only one authority in the world who knows what happens in a beam—and that is the beam itself. My method is to go directly to the beam and ask it "Say my dear, tell me what are your stresses? What is your moment of rupture?"

• **On model testing**—If you want to derive meaningful conclusions, perform your tests on real big beams (60, 70, 100 or 150-ft spans)—not toys of 3 or 4 ft long, 2 or 3 in. deep, which I call confidential beams.

• **On false prophets**—Beware of people who are trying to sell you new patents or prestressing systems. Most of the time these people know very little about engineering or prestressing principles. These devices are only worth considering after full-scale testing.

• **On professional ethics**—If you cannot design a prestressed concrete structure on a sound and economical basis, don't build it! Above all, be an engineer with a professional conscience. Make the structure right!

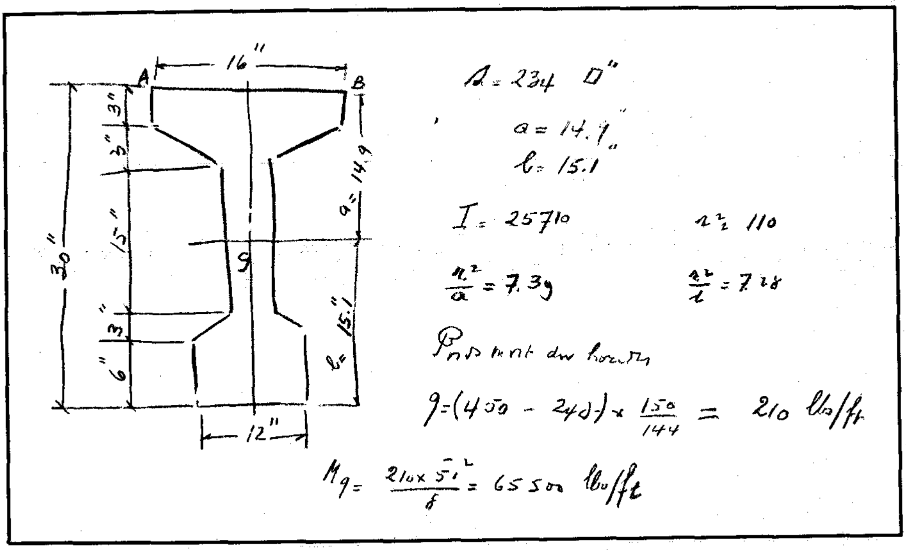


Fig. 9. Portion of an original calculation sheet in Magnel's own handwriting.

thousand copies of the second revised and expanded edition were published in 1950 and a third further expanded edition was published in early 1954.

In view of the book's unexpected success, McGraw-Hill of New York purchased the reprint rights of the third edition, late in 1954.

I am convinced that most copies of the early editions made their way into the United States and Canada, the only major English speaking countries. (Until 1955, when T. Y. Lin published his book on *Design of Prestressed Concrete Structures*[6], Magnel's book was the only English text treating the subject.)

During those early years Magnel's book was the practical tool to which engineering students and practicing engineers referred to for the design and analysis of prestressed concrete structures. The impact this treatise (as well as many of Magnel's other publications*) had on the prestressed concrete industry is indeed significant.

The basic principles, charts, and nomographs generated the necessary confidence in the design of the new material and served as the basis for prestressed concrete publications and engineering practice for many years thereafter.

Fig. 9 shows a portion of an original calculation sheet in Magnel's own handwriting.

The Preload Corp.

During the forties, the Preload Corporation was awarded a sub-contract from the Virginia Construction Company, Norfolk, Virginia** to construct eight prestressed concrete digestion tanks for Philadelphia's North-East Sewerage Disposal Plant.

Preload Corporation thus was in a strategic position to promote linear prestressed concrete in Philadelphia. This can be seen in the following extract from a June 5, 1948, letter to Charles C. Sunderland, Chief Engineer of the John A. Roebling & Sons Company from E. R.

*Magnel was a prolific writer. He published about 200 technical articles and books between 1910 and 1955.

**The Virginia Construction Company is now called Basic Construction Company, Inc.

Schofield, Principal Assistant Engineer in the Department of Public Works, Bureau of Engineering, Surveying and Zoning, Philadelphia:

> "Since I saw you last April several things have happened to our Walnut Lane Bridge. The Pre-Load Co. (sic) who are building some digestion tanks for us requested permission to study the problem. Although I did not like the situation I could hardly refuse, my position being what it is. At the time I was very enthusiastic about Mr. Coff's* plan but did not like the probable erection difficulties. . .
>
> "In studying the proposed Walnut Lane Bridge, the Preload Corporation went to Europe and hired Professor Magnel. He proposed a prestressed girder bridge similar to those which had been built in Europe. Part of that proposal was to make girders with an 'I' shaped cross section and with a uniform depth of about 6 ft 6 in. (2 m).
>
> ". . . Please note that the intention is to cast the 'I' section girders at the site and place them in position on the piers and abutments by launching. The girders will be pulled together by transverse wires placed at the top and bottom of the diaphragms [about 14 ft (4.3 m) apart]. The tops of adjacent 'I' sections will touch each other on the main span and the wearing surface will be placed directly upon the tops of the I's. On the approach spans every other girder is omitted and the deck becomes a poured-in-place problem as are the cantilever sidewalk brackets of the main span . . .
>
> ". . . There are several things I like about this solution, the first being the economy of one set of molds or forms for all girders, another being the fact that enough bridges have been and are being built in Europe to have established precedents for the basic design and method of prestressing and erection."

Some months before this letter had been written, I had joined the Preload Corporation as Design Engineer and was assigned to the task of promoting, developing and designing linear prestressed concrete structures using the Blaton-Magnel cable system and anchorages.

This was a logical assignment in view of my relationship with Professor Magnel and my knowledge of European and American design and construction practices.

It was in this capacity that I presented Magnel's plan in the early spring of 1948. I entered Ed Schofield's office, stood in front of his desk, faced him, and slowly unrolled the large drawing Professor Magnel had developed showing a plan, elevation, cross section and a rendering of a proposed prestressed concrete Walnut Lane Bridge.

As I stood there, silently holding up the drawing, Schofield examined it intensely (his eyeglasses on the tip of his nose) and then pronounced the magic words we all had hoped to hear: "Yes, that's what I want[7]—let me have the drawing." He hurried off, drawing in hand, but soon returned and said, "They like it upstairs."

"Upstairs" meant the offices of the Philadelphia officials for the Bureau of Engineering, Surveys and Zoning. These officials included Thomas Buckley, director; A. Zane Hoffman, chief engineer; and Samuel Baxter, assistant engineer. Edward Schofield was then the principal assistant engineer. "They like it," was tantamount to a final approval but Schofield said, "Well, we need one more approval. Let's go."

Ed Thwaits (at the time, vice-president and sales manager for the Preload Corporation)** had accompanied me and, together with Schofield, we set out for the office of Roy Larson, architect and

---

*L. Coff, a consulting engineer in New York, had developed, as consultant to John A. Roebling & Sons Company, a prestressed concrete box girder of variable depth for a Walnut Lane Bridge using cables made up of galvanized strands provided with sockets and swage terminal for anchorages, and bridge saddles over transverse diaphragms, similar to the cables used in suspension bridges.

**Ed Thwaits is now 85 years old and lives quietly in Denver, Colorado.

chairman of Philadelphia's Art Commission. Any proposed public structure in Philadelphia is subject to approval by the Art Commission but with particular scrutiny if located in beautiful Fairmount Park, the largest park to be contained within a city's limits.

As we waited, Schofield again went "upstairs" but returned all smiles saying, "Well, that's finished business. Larson approved it. It's lunchtime; let's have a bite to eat," We were all elated. The drama and suspense was over. Walnut Lane Bridge as it now stands was accepted there and then after another version, a single 212-ft (64 m) simply supported span, had been rejected by Schofield as being too daring.

One should bear in mind that a public transportation official has the enormous responsibility of protecting the life and safety of the public. To convince a public official of the merits of a new construction method is a difficult task, particularly since Americans advocating its use only had a second-hand knowledge of prestressed concrete. It takes vision, daring and courage for a public official to accept the challenge and to proceed with such a project.

Contractor Emile Blaton said it well:

> "Ah! Those Americans. They have guts. When we started prestressed concrete, we built first a beam having a 20-ft (≈6 m) span, then, when we had learned how to do that well, we made a 40-ft (≈12 m) beam, and then a 50-ft (≈15 m) beam, we progressed step by step. But the Americans! No, they have to start their first prestressed concrete bridge with 160 and 74-ft (≈49 and 23 m) spans."

And he shook his head in disbelief.

It was the culmination of several months of persistent hard work by Professor Magnel, his staff, the Belgian contracting firm of Blaton Aubert who held the patent rights to the anchorage system as builders of many Belgian prestressed structures, and the staff of the Preload Corporation.

Constructing the Walnut Lane Bridge

In retrospect, one now sees how the project fell into place: The roles of the Belgian-American Educational Foundation, Gustave Magnel,[8] the laboratory testing of full-sized beams, the manuscript, the business acumen and drive of the Preload Corporation, and finally the vision and daring of Philadelphia officials of the Bureau of Engineering, Surveys and Zoning.

Magnel's manuscript, in my handwriting, proved invaluable because it gave Schofield and Baxter the necessary confidence in the design methods and testing methods and results of full-sized members developed by Magnel.

What remained were months of intense office work. Between Magnel's office in Ghent, Preload's in New York and the Bureau of Engineering of the City of Philadelphia, design and detail work had to be coordinated. A complete set of construction drawings and specifications in accordance with American practice required preparation.

Most of the detail work was carried out by Ted Gutt* under my supervision. Gutt was part of Preload's staff and later became resident engineer and field supervisor for construction of California's first prestressed concrete bridge, the Arroyo Seco Pedestrian Overpass.

By late summer of 1948, the City's contract documents were completed.

Fig. 11 (on the next two facing pages) shows two of the original contract drawings (simplified).

It is worth noting that the contract included a clause requiring testing, to destruction, a full-sized main span girder of about 160 ft (48 m) at the bridge site.[9,10]

Fig. 10 shows portions of Magnel's

*Ted Gutt is presently the Chairman of PCI's Plant Certification Committee and an Assistant Vice-President of the Prestressed and Architectural Concrete Division of the Tanner Companies.

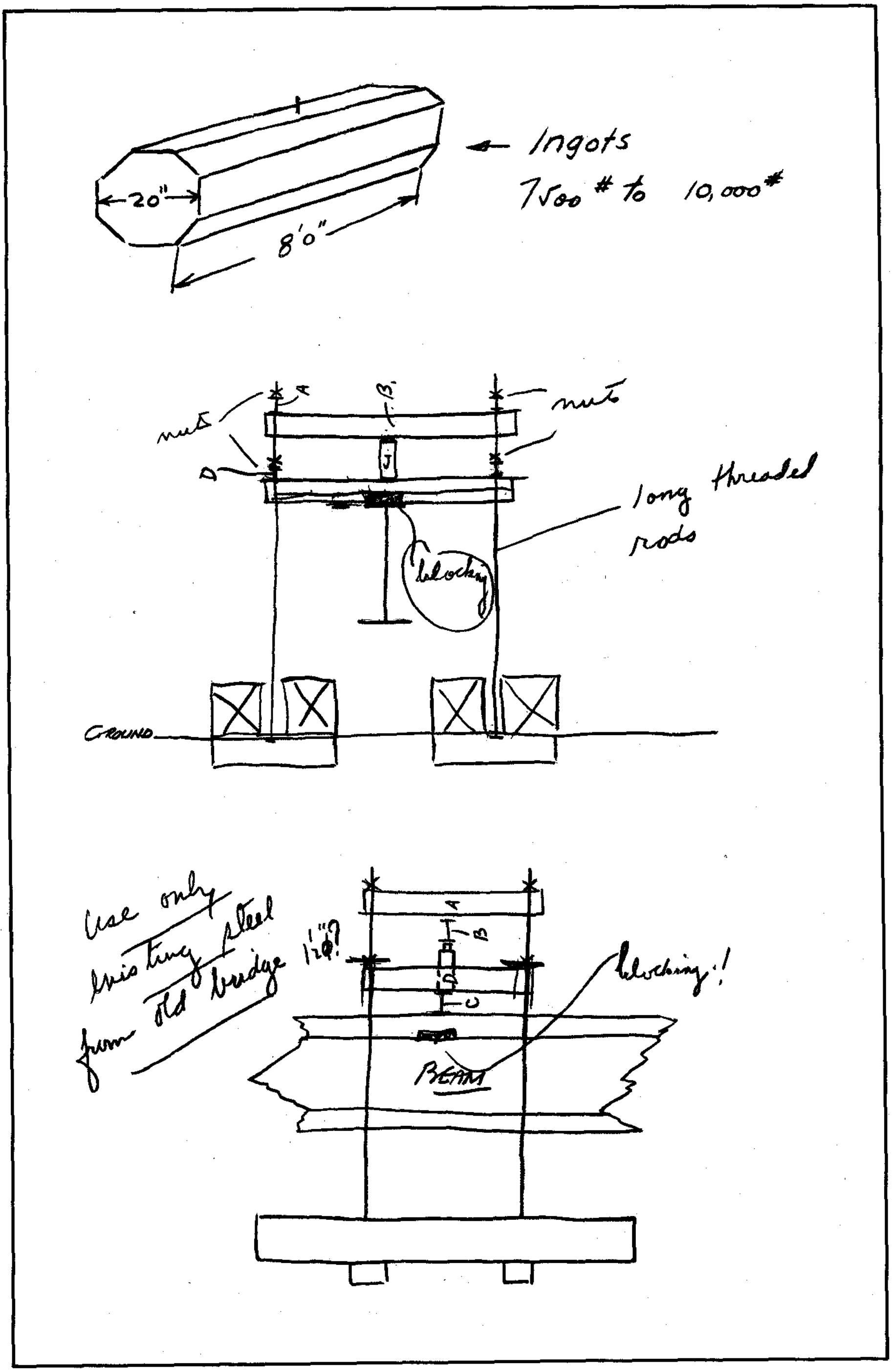
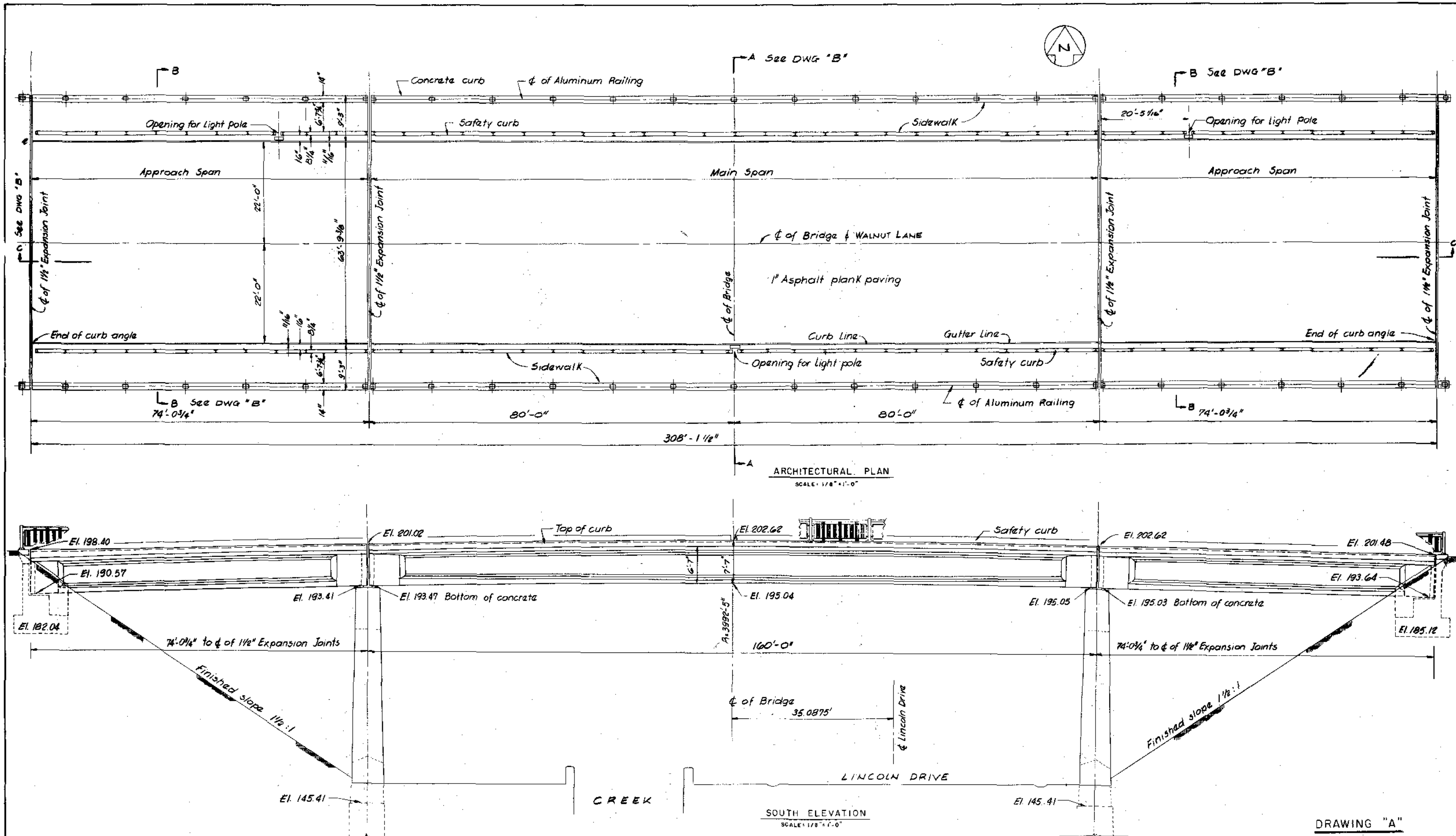


Fig. 10. Portions of Magnel's original rough sketches of the proposed testing arrangement for a 160-ft (49 m) girder used in the main span of the Walnut Lane Bridge. For contrast refer to the actual drawings (see Fig. 15).



N
A See DWG "B"
B See DWG "B"
Concrete curb
¢ of Aluminum Railing
Opening for light pole
Safety curb
Sidewalk
20'-5 1/16"
Approach Span
Main Span
¢ of 1½" Expansion Joint
22'-0"
63'-9 1/8"
¢ of Bridge ¢ WALNUT LANE
1" Asphalt plank paving
¢ of Bridge
End of curb angle
Curb Line
Gutter Line
74'-0¾"
80'-0"
308'-1½"
ARCHITECTURAL PLAN
SCALE: 1/8" = 1'-0"
El. 198.40
El. 201.02
Top of curb
El. 202.62
Safety curb
El. 201.48
El. 190.57
El. 193.41
El. 193.47 Bottom of concrete
El. 195.04
El. 195.05
El. 195.03 Bottom of concrete
El. 193.64
El. 182.04
El. 185.12
74'-0¾" to ¢ of 1½" Expansion Joints
160'-0"
R=3992'-5"
Finished slope 1½:1
¢ of Bridge
35.0875'
¢ Lincoln Drive
LINCOLN DRIVE
CREEK
El. 145.41
SOUTH ELEVATION
SCALE: 1/8" = 1'-0"

DRAWING "A"

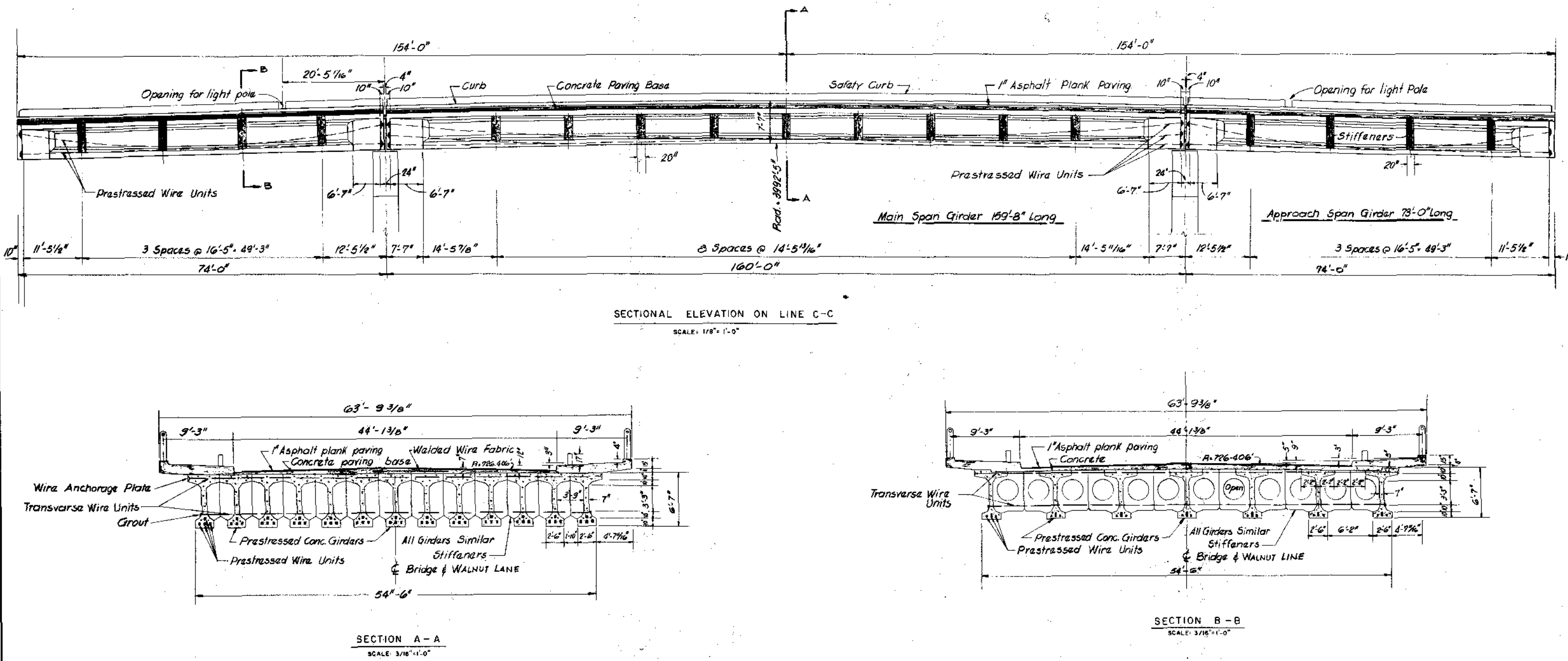


Fig. 11. Original contract drawings (with some detail simplification) of Walnut Lane Bridge showing the plan, various elevations and typical cross sections of the structure.

DRAWING "B"

IMPORTANT FIRST—Look for bids to be asked soon for a prestressed concrete bridge, first in the U. S. Look also for an article on it in a near-future issue of this journal. Philadelphia's department of public works has been quietly designing the structure these past several months. Of deck-girder type, it will have a center span of 160 ft., end spans of 74 ft. The largest of the girders will weigh 150 tons. Precast, they will be lifted into place 50 ft. above a drive in Fairmount Park.

Fig. 12. "The Philadelphia Inquirer's" announcement of the bid opening for the Walnut Lane Bridge, December 1, 1948. Bids were taken on January 19, 1949. The contract was awarded in the spring of 1949.

original rough sketches of the proposed testing arrangement for a 160-ft (49 m) girder of the Walnut Lane Bridge.

Bids were let on January 19, 1949 (see Fig. 12) leaving only one unexpected hurdle to overcome.

A joint venture of Corbetta Construction Company and Raymond Concrete Pile Inc. submitted a low bid based on an alternate Freyssinet design. After protracted discussions, the bid was rejected as not conforming to the contract documents.

This alternate design called for 14 girders in the main span whereas the basic design consisted of 13 girders. Indeed, the Freyssinet stressing jack, at that time, was unable to pull the force pro-

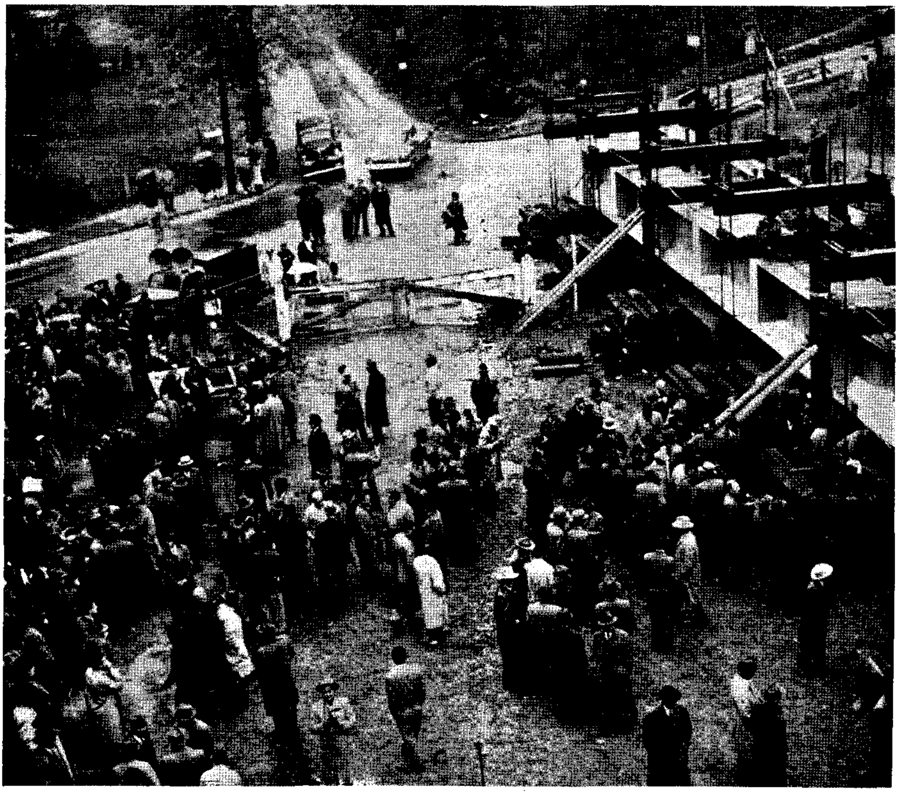


Fig. 13. Over 300 engineers from 17 states and 5 countries witnessed the formal testing to destruction of an identical girder used in the main span of the bridge.

vided by 0.276-in. (7 mm) diameter wires but was limited to pulling 0.196-in. (5 mm) diameter wire.

It was not possible to accommodate the large number of 0.196-in. (5 mm) wires required in 13 girders. Therefore, with the alternate design a 14-girder main span was essential. This caused an esthetic problem in aligning girders when the approach spans were taken into consideration.

A contract was finally awarded in the Spring of 1949 to the Henry W. Horst Company for the construction of the original design in the amount of $698,383; the second lowest bid was $705,706.50.[11] The Preload Corporation was awarded the sub-contract to fabricate the girders.

Load Testing to Destruction

Testing of the 160 ft (49 m) long and 6 ft 7 in. (2 m) deep girder, identical to the girders forming the center span of the bridge, was conducted on October 25, 1949 (see Fig. 13) adjacent to the site of the bridge. This test demonstration attracted some 300 engineers from seventeen states and five countries—England, Cuba, Mexico, Canada and Belgium—who stood in the rain for the entire day to witness the drama.[12]

Professor Magnel himself (Fig. 14) supervised the formal test demonstration and provided his appreciative audience with a running commentary (interspersed with his usual witty humor despite the rainy conditions) on the progress of the test.

To the astonishment of some skeptics, the Professor correctly predicted the behavior of the girder during each loading phase and foretold the favorable outcome of the load test.

Fig. 15 is a diagram of the typical jacking frame and Figs. 16a and 16b show the general testing arrangement and details of the testing frame, respectively.

Figs. 17 and 18 show the behavior of the girder during its various testing stages from initial loading to final destruction.

Fig. 14. A very happy Professor Magnel conducted the test demonstration and delighted the spectators with his humorous running commentary.

The girder had to be loaded to between 10 to 11 times its working load, i.e., loads were gradually increased to 5000 lbs per lineal ft (≈7500 kg/m), to cause failure. Failure occurred through compression of the concrete in the upper flange.

This 5000 lb per lineal ft per load corresponds to a total superimposed load of some 800,000 lbs (≈360,000 kgs). At this point the deflection at midspan of the 160-ft (≈49 m) long beam was only slightly more than 15 in. (≈38 cm).

It is noteworthy to mention that the first crack occurred at an equivalent load of 1400 lbs per ft (≈2100 kg/m). The deflection was only 11/16th of an inch (≈2 cm).

As the loading was continued, the crack widened but at a load of 1500 lbs

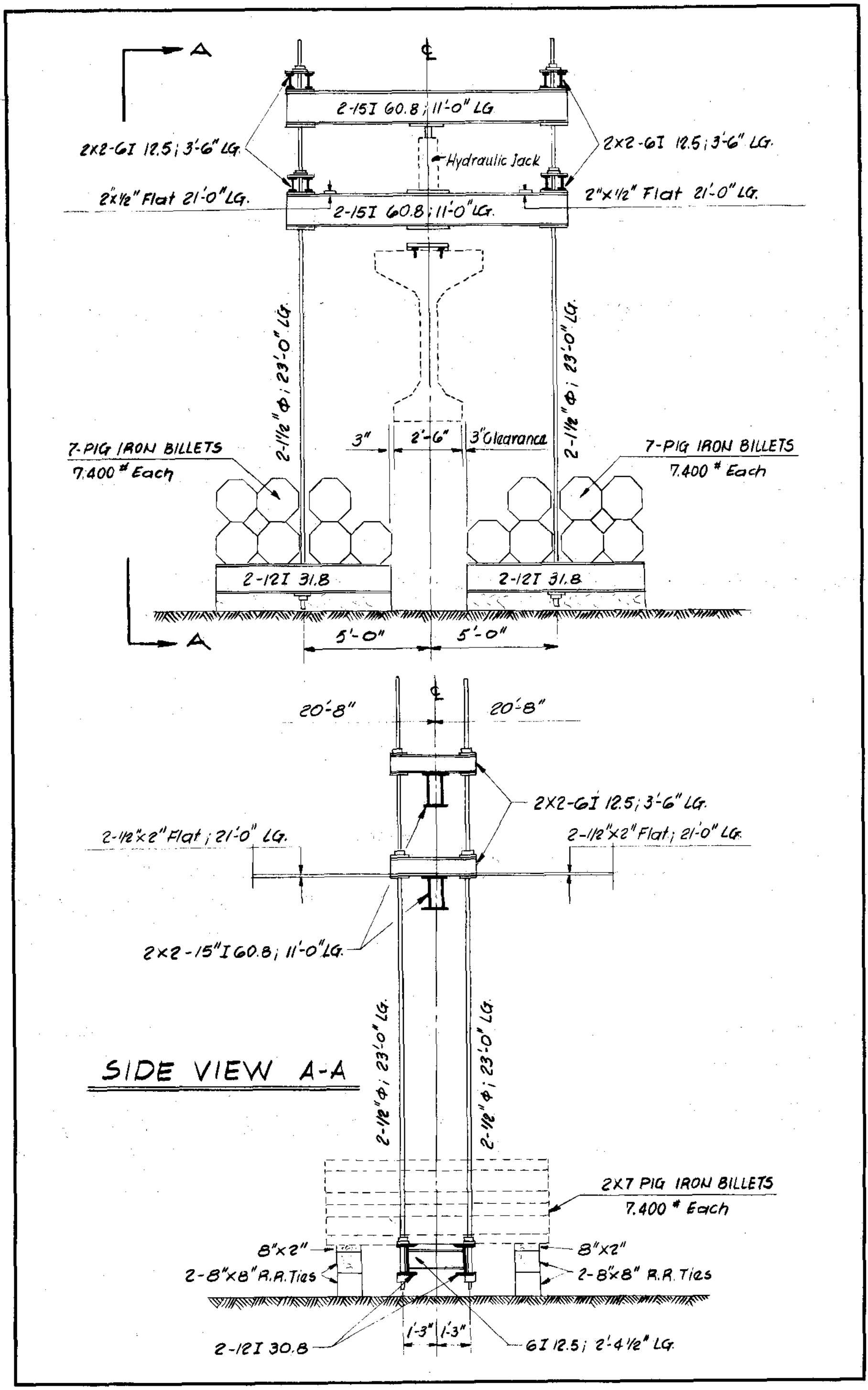


Fig. 15. Elevation and section of typical jacking frame (for contrast see Fig. 10).

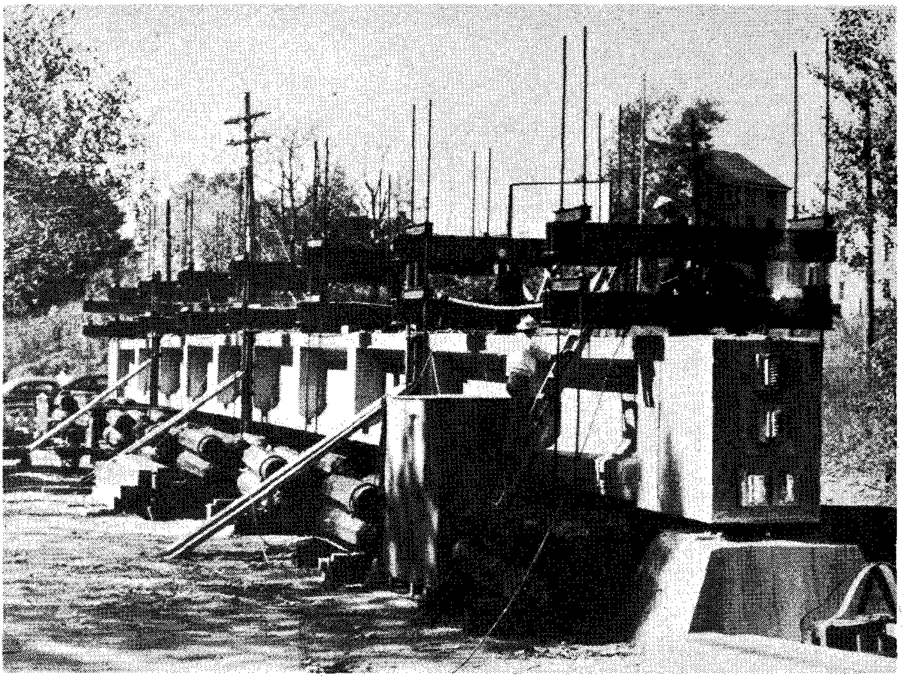


Fig. 16a. General testing arrangement.

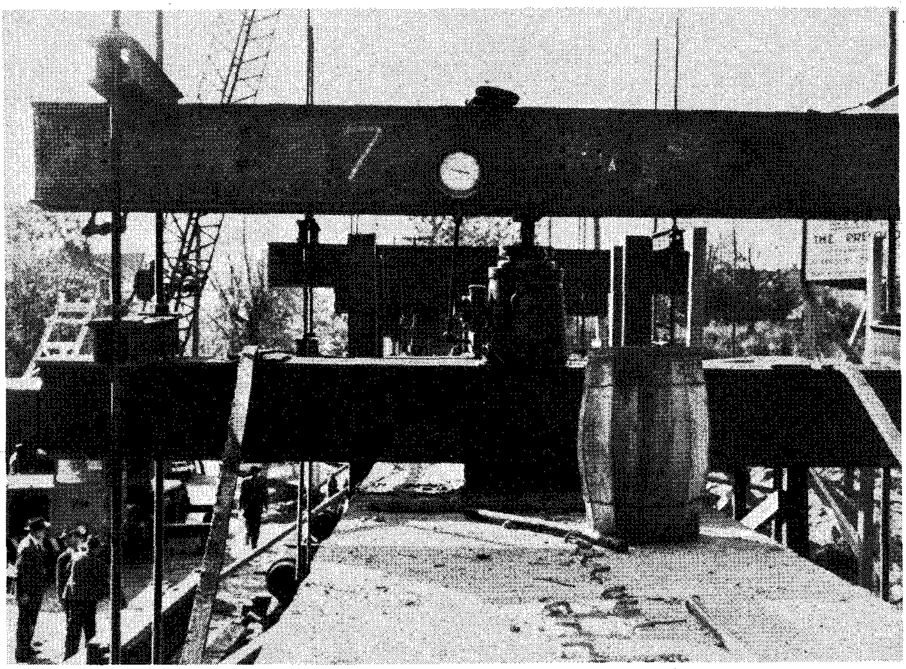
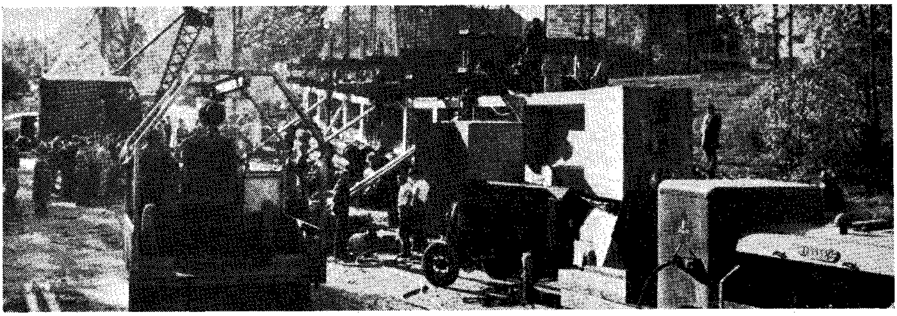
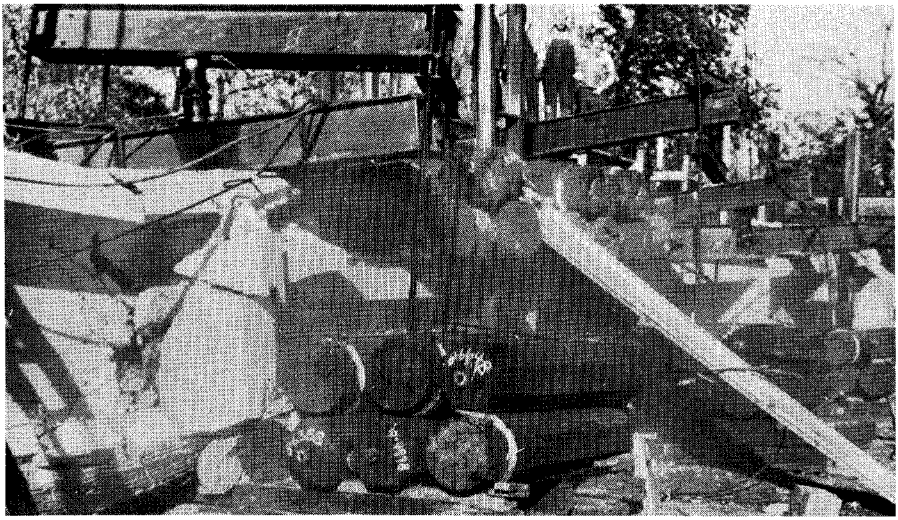


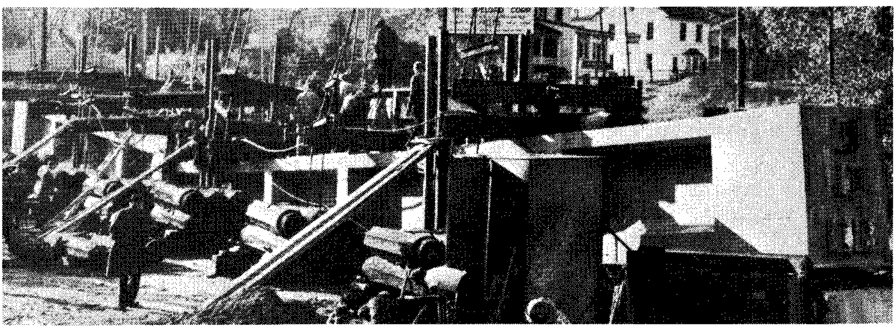
Fig. 16b. Closeup of testing frame.



(a) Deflection of girder prior to failure.



(b) Girder at moment of failure.



(c) Girder after failure.

Figs. 17. Although the girder did not fail at the designated testing load "informal" testing continued the following day (ironically, in clear sunny weather). The girder finally cracked at the superimposed load of more than 1.2 million lbs.

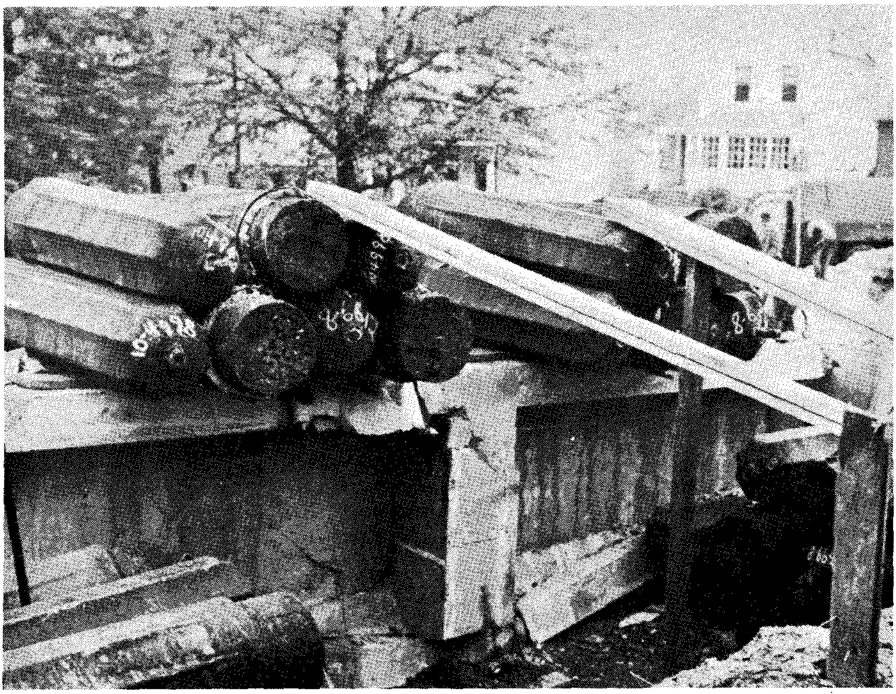


Fig. 18a. Closeup of failure at midspan.

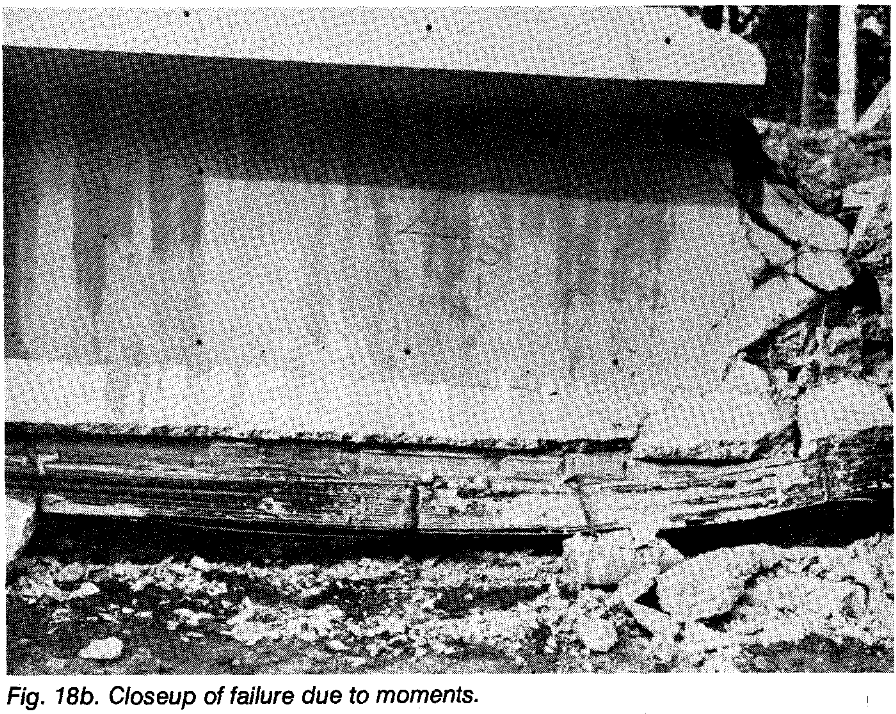


Fig. 18b. Closeup of failure due to moments.

Fig. 19. A year before Magnel's death, the Professor (center) admires the Walnut Lane Bridge with Charles Zollman (left) his former student and good friend, and Samuel Baxter (right).

per ft (≈2200 kg/m) other cracks appeared in the panels next to the central stiffener. Up to this time, there was no noticeable deflection in the girder.

The formal test was arranged to simulate uniform loading throughout the length of the girder. This was accomplished by means of eight jacks placed 20 ft 8 in. (6.3 m) on center on top of the girder (see Figs. 16a and 16b).

Again, it should be noted that although load testing was continued for most of the day, the girder did not fail that day. The next day (a beautiful day in contrast to the previous one), after the ingots had been rearranged the beam was destroyed.

For the record it should be mentioned that Dr. Arthur R. Anderson (at the time a consulting engineer in Springdale, Connecticut) was in full charge of the delicate instrumentation, the strain readings and the deflection measurements.

The successful testing to destruction at the job site (and in front of a large audience) of the 160-ft (49m) long girder, 6 ft 7 in. (≈2 m) deep and weighing an average of 2000 lb per ft (3000 kg/m), far away from the comforts of a laboratory, was a significant achievement which instilled public confidence in prestressed concrete.

To have devised simple but sufficiently accurate means for synchronizing and controlling load increments at eight different locations along the girder is a credit to American engineers. For none of these techniques had been previously associated with linear prestressing.

After the bridge was completed, Professor Magnel visited the site with his old friends to admire the structure (see Fig. 19 and 20).

The Aftermath

After the contract was awarded to the Henry W. Horst Company, a group composed of those responsible for constructing the Walnut Lane Bridge travelled to Europe to inspect prestressed concrete construction (especially bridges).[13] The group included Anthony Horst of the Henry W. Horst Company, Robert Petersen and Ben Baskin of Concrete Products of America,* Sam Baxter, Ed Schofield and myself.

We were met at the Brussels airport by Professor Magnel who joined us in a sumptuous dinner. Tony Horst, who had

*In 1949, they built the first American pretensioning plant for the manufacture of box girders, at Pottstown, Pennsylvania. Another first!

Fig. 20. The completed Walnut Lane Bridge and the men responsible for its construction; (from left to right) Prof. Magnel, Samuel Baxter (ASCE) and Charles Zollman (author of this paper).

been extremely concerned about the concrete strength and slump specifications asked Professor Magnel, "Is it true that you requested zero slump?" The Professor answered with a smile, "I am not talking about zero slump, I am talking about 'minus' slump." But then, that is another story.

And so is the one about William A. Dean, one of the men instrumental in developing prestressed concrete, especially in Florida. In 1949, I met Bill Dean, then bridge engineer for the State of Florida. He greeted me by saying, "I have gone sour on prestressed concrete."

However, shortly afterward, Dean did proceed with the design of the 17,500 ft ($\approx$ 5300 m) long prestressed concrete Sunshine Skyway Trestle between Bradenton and St. Petersburg, Florida. In 1957, he received ASCE's distinguished Ernest E. Howard Award for "achievements in the design and construction of prestressed concrete."

The ball was beginning to roll—soon to pickup momentum in Florida, the Midwest, and on the West Coast.

The second part of this article will reveal how the ball was made to roll making the prestressed concrete industry a giant in American construction.

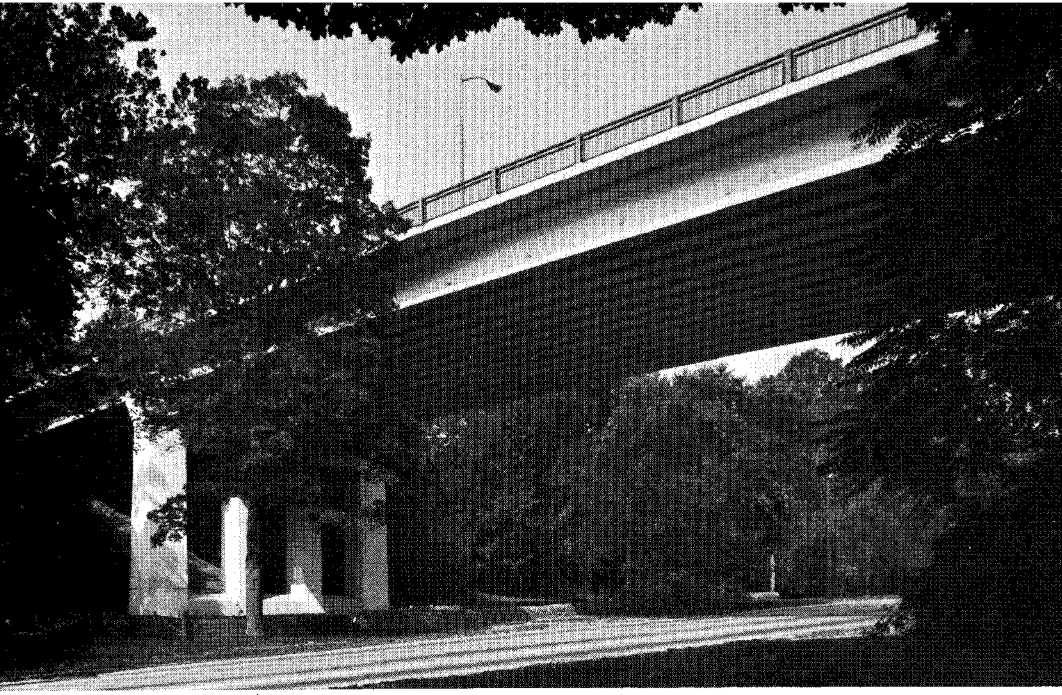


Fig. 21. Walnut Lane Bridge as it looks today.

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