WHAT HAS BEEN LEARNED FROM THE FIRST PRESTRESSED CONC. BRIDGES-REPAIR OF SUCH BRIDGES

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Engineers often wonder to what extent prototype structures have lived up to their expectations. As examples, old construction of the Walnut Lane Bridge, Amdeck section, and one other structure which showed signs of distress over the years will be illustrated. The speaker will discuss the apparent background and reasons for such a distress plus the improvements which may be made to make such effects less severe. Also, methods of repair and what has been learned from these old designs will be described. The lecture is supported with many color slides and viewgraphs which depict old construction details and the increasing severity of distress. Accidental damages caused by vehicles on three different types of prestressed bridge superstructures are also illustrated.

History

Modern use of commercial prestressed concrete was introduced by E. Freyssinet of France, who in the late 1920's started using high strength steel wires for prestressing. (1) Although others before him worked on, designed, or received patents on prestressing systems, it was Freyssinet who identified the conditions and established the parameters under which it is possible to assess strains in concrete, and clarified methods to apply a prestress force which give the predicted strains. (2)

Use of Prestressed Concrete in North America started at the beginning of the 1950's. The structure most often mentioned in magazine articles and in text books is the Walnut Lane Bridge in Philadelphia which was conceived in the late 1940's.

There are several claims for the position of "first" in prestressed concrete bridges. According to the Engineering News Record, (3) the first prestressed bridge was completed in October 1950 in Madison County, Tennessee. On the other hand, PennDOT records reserve this distinction for a bridge near Hershey in Pennsylvania, and also for the Walnut Lane Bridge in Philadelphia, Pennsylvania.

However, these claims to fame can be divided into different phases, i.e.: being first in prestressed concrete bridge design, start of construction, completion of construction, and opening to traffic. When examing the facts closer, each of these claims is bona fide and can be supported for the following technical reasons:

Walnut Lane Bridge

Located in Philadelphia, Pennsylvania. This is the first prestressed (post tensioned) bridge in the USA using site cast I girders (bulb T type, with wide top-flange).

Main span girders 48.8 m (160 ft.) long, 2 m (6 ft. - 7 in.) deep and weighing 122 mg (135 tons) each were cast on top of 15.2 m (50 ft. high) falsework and piers. The center span girders are prestressed by 4 parallel wire cables, each cable consisting of 64 wires, each wire .7 mm (.276 inch) in diameter and stressed to 862 kPa (125,000 psi).

Two cables were parabolic and two straight. The girders have 8 web stiffeners (7) and are assembled to form a superstructure which would now resemble an adjacent AASHTO, Type VI Beam Superstructure.

An interesting sound movie had been prepared by the Portland Cement Association, a copy of which was still available from the PCA a few years ago.

Construction of the first main span girder, which was test loaded under the supervision of Professor Gustave Magnel (7) to destruction under a force of ten times the design live load, began in the fall of 1949. After the successful load test of this girder, construction of other girders started and continued through the winter. The deck was completed in the fall of 1950. The bridge was opened to traffic in February 1951. (5) Fig. 1.

Madison County Bridge

Located in Tennessee, this structure used beams assembled from precast concrete blocks compressed to form a monolithic unit by tensioning 7 wire galvanized strands.

"This pioneering structure consists of a cast-in-place concrete deck carried on 6.1 m (20 ft.) and 9.1 m (30 ft.) beams placed side by side. (4) The beams were built up of 20.3 x 40.6 x 30.5 cm (8 x 16 by 12 inches) deep, machine made hollow concrete blocks, which were battered on opposite sides with mortar and threaded on tensioning cable." (This tensioning work for the multiple span bridge was done by the county highway maintenance crews.)

"Cable are 7 wire bridge strands with anchor fittings made by John Roebling's Sons Co. at both ends. Tensioning was done with hydraulic jacks. The first day, an initial tension of 4536 kg (10,000 lb.) per strand was applied and the mortar allowed to set overnight. The next day, a final prestress of 11793 kg (26,000 lb.) was applied, giving the strands a prestress of about 862 kPa (125,000 psi).

Fabricated in the field by the county maintenance crew in three days, the beams were erected and the bridge opened to traffic in less then two weeks after construction began." (4)

Designed by Ross H. Bryan and Culver B. Dozier and built in October 1950, this bridge was heralded as opening up a new market. (Fig. 2)

Figure 1. Walnut Lane Bridge, Philadelphia.

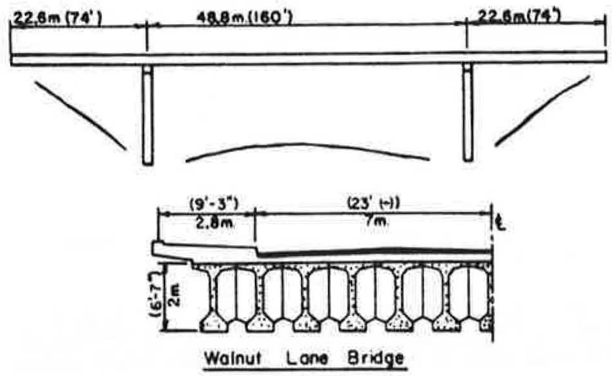
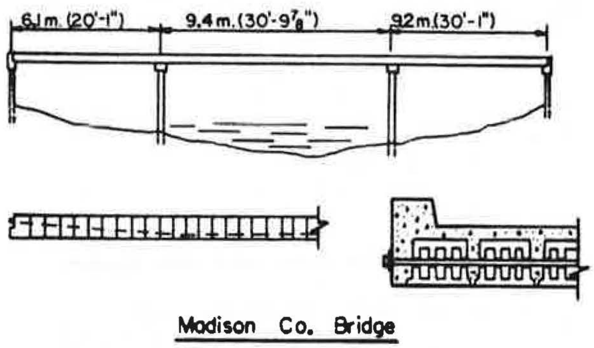


Figure 2. Madison County Bridge, Tennessee.



Hershey Bridge

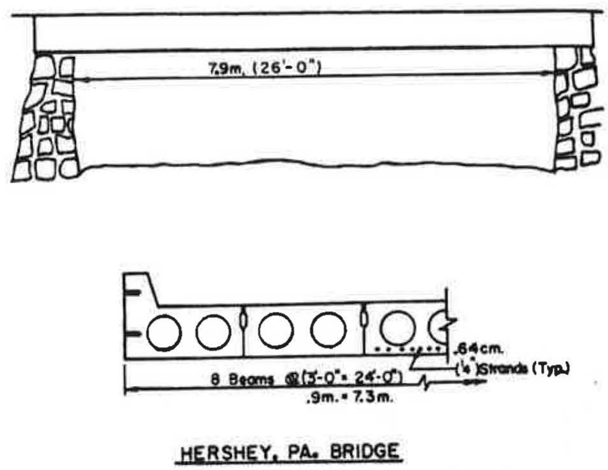
Located in Pennsylvania, "In December, 1951, pretensioning took a bow in the United States, when a 7.3 m (24 ft.) span-consisting of rectangular beams laid side by side to form a 6.7 m (22 ft.) roadway-was erected near Hershey, Pennsylvania."(8) (9)

One of the pretensioned prestressed concrete bridge members was test-loaded to destruction May 20, 1950 at the Pottstown Plant of Concrete Products of America (which was the longest continuously operating prestressing plant in the USA until it changed ownerships; first to American-Marietta Co. (Martin Marietta Co. then to Pottstown Newcrete). Another beam was fatigue-loaded at Lehigh University, July 1951. (10)

It is interesting that, since May 1947, this plant had fabricated Precast Reinforced Concrete Channel beams for Pennsylvania, and then switched over to prestressed concrete bridge beams in 1950.

According to PennDOT records this first bridge had a clear span of 7.9 m (26 ft.) and is 7.3 m (24 ft.) wide. (Fig. 3)

Figure 3. Hershey Bridge, Pennsylvania.



What does a short selective history of USA prestressing tell us? It says that when a good idea such as prestressing comes along and the time is right, many will have similar ideas.

In summary, the Walnut Lane Bridge was the first cast-in-place post tensioned concrete bridge, completed in the Fall of 1950 and opened to traffic, February 1951. First beam was load tested, Fall of 1949.

The Madison County Bridge was the first segmental precast post tensioned concrete block bridge, completed Fall of 1950, and opened to traffic, October 28, 1950.

The Hershey Bridge was the first precast pretensioned concrete box beam bridge, and was completed December 1951, and a test beam was load tested May 20, 1950.

I think that it really does not matter who was first in designing a prestressed bridge, or who was first in building a prestressed bridge beam, or who was first in test loading such a bridge beam, or first in completing a prestressed bridge or who first had traffic on it; what matters is that each bridge of the three precedent-setting bridge types represent a pioneering effort in bridge construction. Such effort was only possible by the pooling of the efforts of many talented engineers, contractors, material suppliers, and government officials, who added to and converted European

Similar Ideas

Such bridges remain a monument to progress. We now know in which direction the technology established by these pioneers developed, and what use is still being made today of the bridge systems developed by them, as well as new direction the prestressed bridge technology has taken.

Design-Construction-Fabrication

It should be understood that only two of the 3 bridge types which received early prominence withstood the test of time. Repeated use of those systems was made after their initial introduction.

Early standards began developing in the early

50's, soon after engineers thought they had a viable product.

It is interesting to note, that of the two surviving bridge types, the I-beam Walnut Lane Bridge consisted of large heavy field-cast bridge members, which were field post tensioned, while the box beam Hershey Bridge was plant-fabricated, and pretensioned, and was, in comparison much lighter in weight.

Design

The first standards were developed by the box beam fabricator, the Concrete Products Company of America. Standards dated November 16, 1951 and August 19, 1952 were distributed showing adjacent box beams with circular voids for clear spans from 5.5 m (18 ft.) to 11 m (36 ft.) in .6 m (2 ft.) increments; and Standards dated December 17, 1951 and subsequent revision showed 83.8 cm (33 in.) deep beams with spans from 11.6 m (38 ft.) to 15.2 m (50 ft.), also with circular voids.

This plant was purchased by the American-Marietta Company, which expanded upon those Standards and issued their famous Amdek Standards, dated December 30, 1955, which had wide distribution at the time. Standards showed all necessary details to build the beams including the number of .95 cm (3/8 in.) strands. These Amdek Standards were further expanded in 1957 and 1959 by American-Marietta Company.

I-beam standards were proposed by the Prestressed Concrete Institute for acceptance under the auspices of the "Joint Committee, American Association of State Highway Officials Committee on Bridges and Structures, and Prestressed Concrete Institute". (printed in 1963, with standards enclosed which were dated 1961)

During the period from 1958 thru 1962, efforts to establish Industry, Statewide or Regional standards proliferated.

As a typical example, I show the national development of Standards by the U.S. Bureau of Public Roads.

Issues were 1956 (11), June 1962 (12), August 1968 (13), and January 1976 (14).

The Federal Standards are in some aspects different from the various State Standards. The difference is generally in the section/wall thickness in box beams, webs or flange configuration in I-beams, or different minimum reinforcement. This difference is readily explained because some Regional State Standards were developed earlier then Federal Standards and took precedence in their respective regions since fabricators had already invested in forms and turned out successful products.

Construction

The most frequently used prestressed bridge stringer systems for prestressed concrete bridges are the I-systems (Walnut Lane Bridge) and the box beam system (Hershey Bridge).

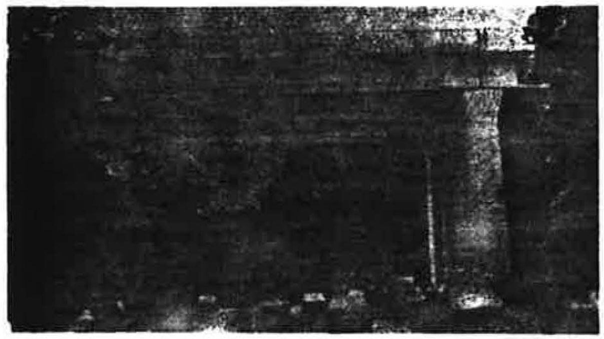
It must be remembered that both systems were properly designed with a more than adequate factor of safety when they were initially conceived and that, as an additional safe guard they were subjected to test loadings. They were only used on an actual structure after they successfully passed the tests.

In the early stages of prestressed concrete development in the United States, the prevailing design philosophy was that "because the concrete was prestressed" it will remain crack free. This philosophy was also expressed in some literature circulating at that time. Because of this, the effects of temperature (temperature reinforcing) and shrinkage were often neglected. Furthermore, there may have been less attention given to prestressed losses than would be given today and in addition, the assumption that net compression could be maintained throughout the section was overly optimistic, since the determination of the effect of force reduction caused by losses was not as sophisticated as today's methods, therefore, resulting in an over estimation of the remaining prestressed forces.

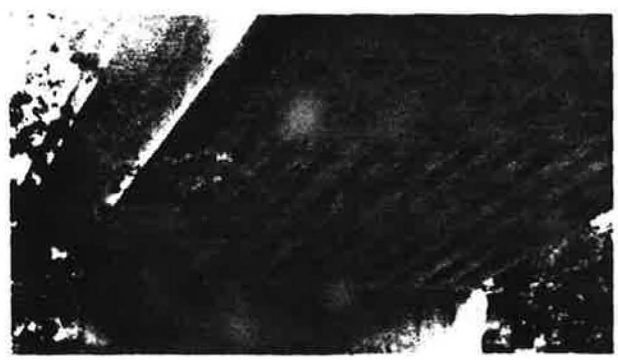
Also, we must recall that at the time of construction (1950) as well as through the following decade, concrete placement was a problem. This was obviously the case with the Walnut Lane Bridge.

If you look at the various construction slides, you receive an overall view of the conditions prevailing at that time.

Slide 1. Shows general view of midspan of Walnut Lane Bridge.



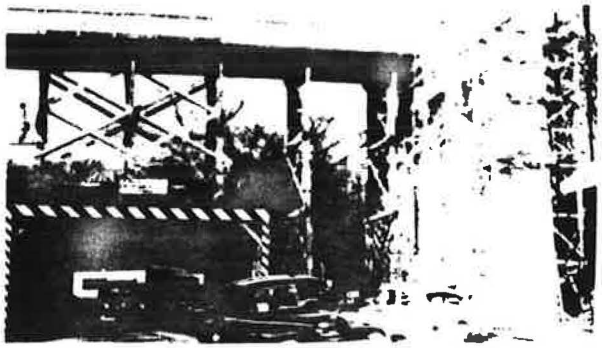
Slide 2. Depicts bottom view of Walnut Lane Bridge showing close intermediate diaphragm spacing.



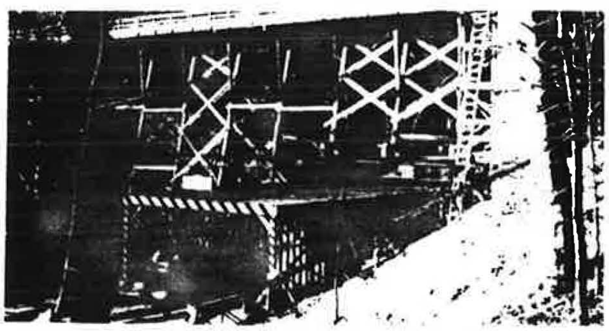
Slide 3. Illustrating closeup of intermediate diaphragms showing weight reducing holes in endspans of Walnut Lane Bridge.

It should be noted that the bridge was being constructed for the City of Philadelphia and now is owned by the Pennsylvania Department of Transportation.

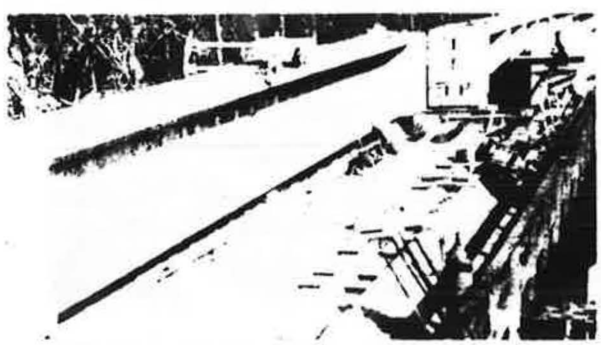
Slide 4. Shows portions of the original falsework of the Walnut Lane Bridge including maintenance of traffic.



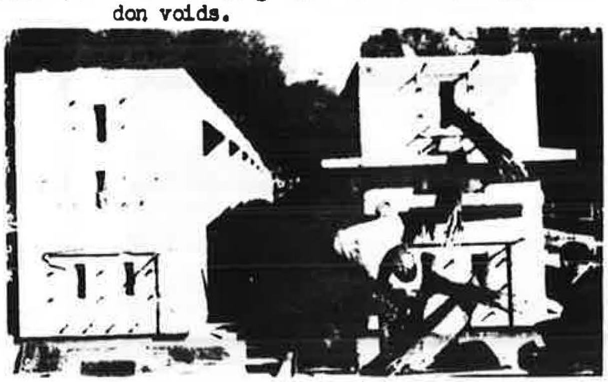
Slide 5. Shows a different view of the same falsework.



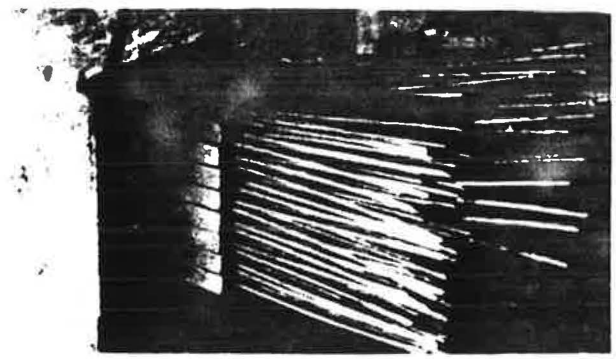
Slide 6. General view of Walnut Lane Bridge, girder on falsework.



Slide 7. End view of girder with tendons and tendon voids.



Slide 8. Closeup of tendons and end anchorages.



Please keep in mind that all the photographs except for slides 1, 2, and 3 were taken in February, 1948 prior to the load test which I previously mentioned.

After the first field cast beam was cured and test loaded, the regular production casting started. But something went wrong in the fabrication of the first production girder - the south fascia girder.

Slide 9 documents this and shows what was wrong with some of the old construction. It is obvious that with thin webs and the large percentage of duct space and the use of wooden forms, low slump concrete could not satisfactorily be placed everywhere.

Fig. 4 shows the Walnut Lane Bridge fascia beam cross section. This should be compared with slide 9.

This bridge had been closely observed by its owner, the City, which found problems. The City retained Zollman Associates early in 1968 as a consultant. The consultant inspected the bridge and reported his findings and recommendations to the City on June 24, 1968.

The report makes interesting reading. Some excerpts follow:

"In November, 1957, a routine inspection made by members of the Maintenance Division of the City's Department of Streets, revealed the existence of longitudinal cracks in the fascia girders of the main span. In addition, there were a number of very localized, fine cracks, hardly visible when observed through binoculars from the floor of the valley some 60 feet below the bridge. There was no pattern to these localized cracks since they occurred erratically throughout the bridge.

The strong discoloration of the concrete in the vicinity of the cracks indicated that they had been present for some time. It also appeared that the cracks had been pointed with grout at some previous time, even though there is apparently no record of this procedure having been carried out. In any event, it was determined that none of the cracks would endanger the structural integrity of the bridge. After the size, type and location of the cracks had been recorded, the City then decided to apply a cement coating to the exposed areas of the girders for the sake of appearances.

Over the next ten years, the cement coating weathered to a point where the cracks again became visible. During a routine inspection made in November of 1967, it was observed that the longitudinal cracks in the South Fascia Girder of the main span seemed to have lengthened and widened. In view of this situation, representatives of the Department decided to inspect all of the girders at close range, and to make and record their observations as accurately as possible."

Slide 9. Construction problem in 1st cast girder.

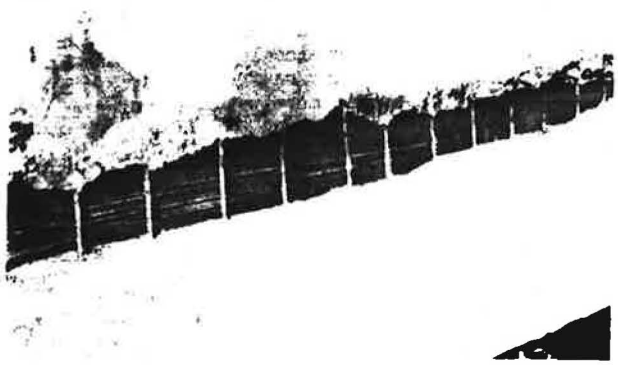
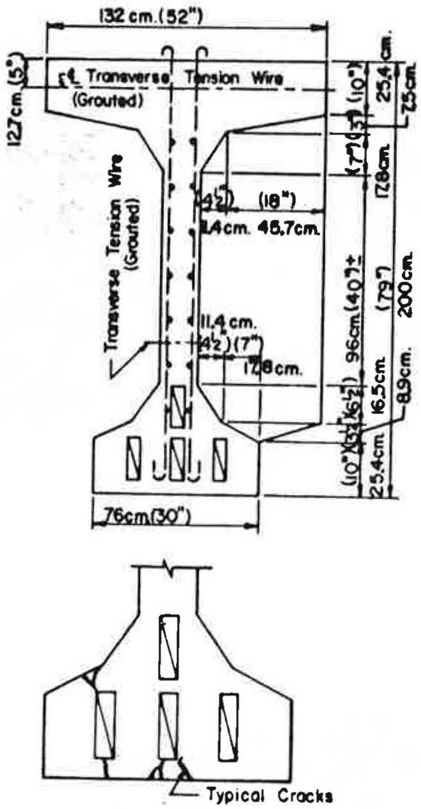


Figure 4. Typical reinforcing in Walnut Lane Bridge girder - also typical cracks shown in large scale detail.



This report also casually mentions the design and construction philosophy prevailing at the early stage of U.S. Prestressed development.

Looking at slide 9, it is obvious what we would do today with such a girder, but at that time, such thoughts were different. I am quoting from the report which indicates that in spite of poor concrete surfaces, honeycombs, exposed reinforcing steel bars, cold joints in bay 4, displacement of vertical web reinforcing steel and displacement of tendon cavities, it was decided that they should proceed with prestressing. The thought at that time was, "if the girder was structurally deficient, the high prestressing forces later to be applied to it would cause the girder to fail." The prestressing was carried out without difficulty, leading to the conclusion that the observed imperfections were of less significance than originally thought. Therefore, the girder was repaired for appearances sake and incorporated into the bridge.

The report gives the following additional observations which are of interest: rectangular duct spaces created an area reduction of 18% of bottom flange and a plane of weakness which was aggravated by possible misalignment of ducts during construction.

Early in load testing, the first cast girder, horizontal cracks unexpectedly appeared near the junction of web and bottom flange on one face. The cracking was not considered to be of any particular consequence, but nevertheless was reported by Gustave Magnel. (7)

In accordance with what was then common practice in prestressed concrete construction, no stirrups were placed in either the top or bottom flange.

Shortly after this report was given to the City, the Pennsylvania Department of Highways became the owner of the bridge.

My office, in cooperation with the office of the Philadelphia District Bridge Engineer, made its own inspection of the bridge, and prepared new repair plans for letting, which relied heavily on the epoxy pressure injection process to seal cracks. The repair/seal work was done by contract during 68/69 and cost about $140,000. (16)

Now it is prudent to look again at a series of slides which depict defects.

Slide 10. Typical cracks found at bottom of fascia beam.

Slide 11. Same crack with some concrete pried out.

Some of the effects of the built-in latent defects previously discussed in connection with Slide 9 are shown in Fig. 5. This figure shows a composite of the cracks and defects selectively copied from construction plans dated October 4, 1968, and shows cracks observed by the Department, and supplemented by cracks recorded on plans prepared by the repair contractor, and dated January and February 1969. The contractor's plans showed cracks found through close visual inspection and listed observations made during the injection process.

Fabrication

Now to the other old structures which, instead of being field cast like the Walnut Lane Bridge, were plant fabricated.

Slide 12. Space between cracks exposing duct space.

Slide 13. Crack in the top of bottom flange.

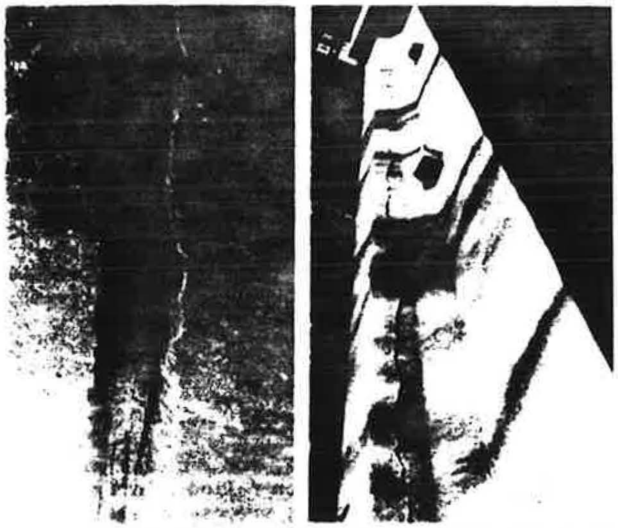
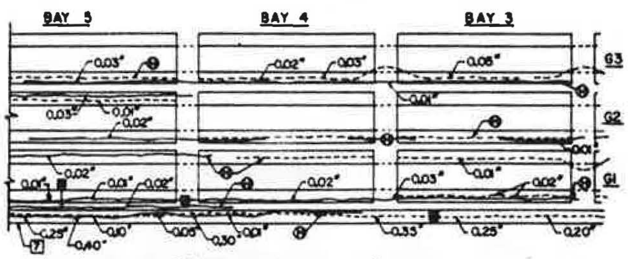


Figure 5. Composite of cracks in a selected area found on Walnut Lane Bridge.



Note: .01" = .25mm. .02" = .51mm. .03" = .76mm. .04" = 1.01mm.

Girder No.	Crack No.	Width of Crack	Length (Approx)	Comments (Vol. Epoxy Injected
G-1	6	0.01" to 0.03"	(100') 30.5m	Water Seepage – (1 Gallon) 3.8 L
G-1	7	Hairline to 0.25"	(75') 22.9m	Water Seepage – (12 Gallon) 45 L
G-1	15	Hairline to 0.02"	(30') 9.1m	Water Seepage – (½ Gallon) 1.9 L
G-1	A	0.01" to 1.7"	(158') 48.2m	— (15 Gallon) 56.8 L

H = Hairline

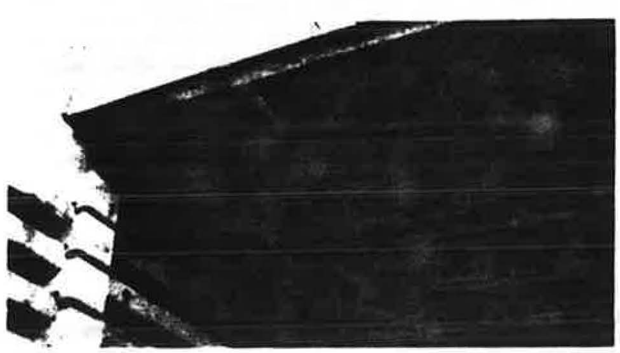
- - - = Cracking on bottom flanges.

—— = Cracking on soffit flanges.

10 form-tie holes in bottom flange of girder, Bays 2,3 & 4 leak water.

Slide 14 shows the predecessor of Prestressed Box Beam Bridges used in Pennsylvania between 1947 and 1951, namely the Precast Channel Section. Anything which is now a problem with this bridge will show up in the future on older Prestressed Concrete Boxes; it is just a matter of time.

Slide 14. Precast channel bridge built in 1947-51 predecessor of prestressed box beam bridges.

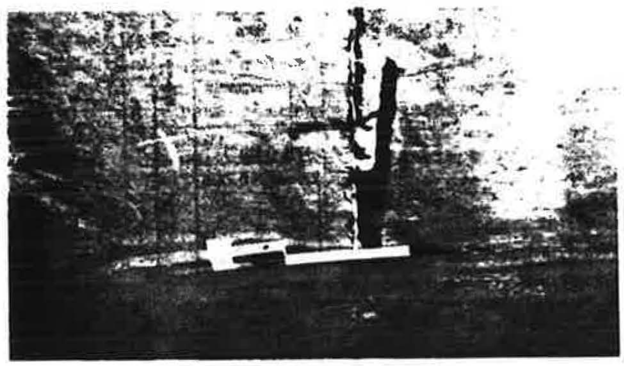


The bridge spans a creek and the deterioration is caused by the moisture-condensation effect on inadequate concrete cover for this exposure condition. The worst damages are visible on the inside leg of the fascia beam/outside leg of interior beam since condensation of moisture from the stream and the environment generates more wetting cycles at those locations than elsewhere.

Slide 15 shows the bottom of the Hershey Bridge Beam and clearly shows the imprint left by the vacuum curing process used for this beam and for all beams produced in Pennsylvania from 1951 thru 1955, and for some bridge beams produced by a certain plant to 1959.

While the placing of concrete for some girders on the Walnut Lane Bridge was a problem, the precaster at that time bypassed this problem by using high slump concrete for placement, and the vacuum process for removal of excess water, in order to gain high early strength for speedy release of prestressed force, therefore avoiding the problems of frequent honey combing.

Slide 15. Hershey Bridge with vacuum cured surfaces.



Slide 16. Outside surface of Hershey Bridge fascia beam in distress.

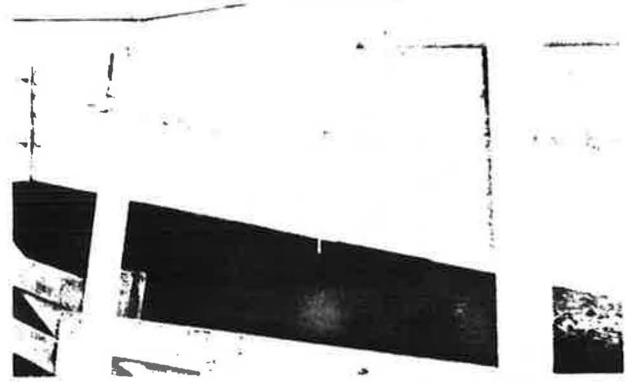
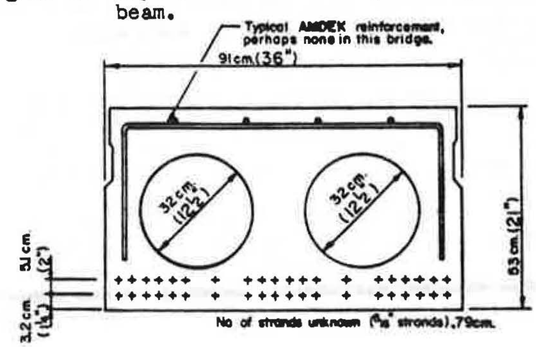
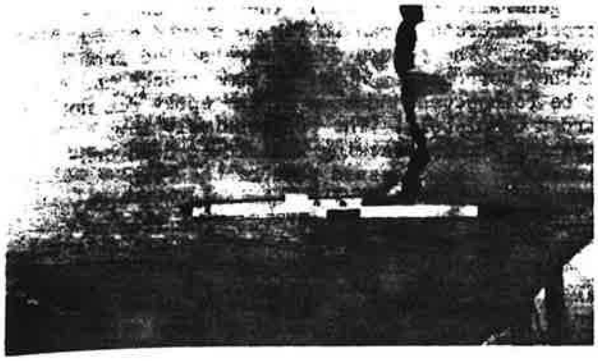


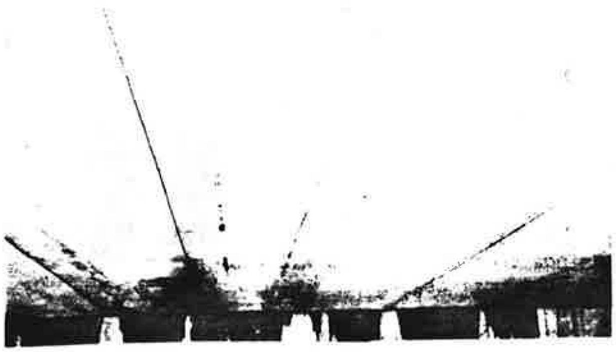
Figure 6. Typical cross section, Hershey bridge beam.



Slide 17. Fascia beam in distress.



Slide 18. A 1956 adjacent box beam bridge but photographed in 1962



Slide 19. View of further deterioration in 1977.

Slide 17 shows the outside surface of one fascia beam showing some surface distress.

Fig. 7 shows the beam cross section as restructured from existing documents. Slide 17 shows the cause for the surface distress in the fascia beam shown in slide 16, namely the damage caused by free water freezing in the beam void and rupturing it.

This type of damage, even though noted on about 10 more bridges, was only observed on fasica beams. This damage was avoided since 1959/60 with the introduction of bottom drains in all voided Prestressed Box Beam Girders.

Slide 18 taken in 1962 shows an early adjacent box beam bridge, approximately 1956 vintage, which shows progressive corrosion due to insufficient concrete cover over the bottom strands of a bridge over a stream. I recall a .63 cm ($\frac{1}{4}$ in.) clearance in some locations while plans specified 3.18 cm ($1\frac{1}{4}$ in.) clear.

Repair/Maintenance of Prestressed Bridges

There are some governing but apparently conflicting observations and suggestions:

As is demonstrated by these slides, which show defects in the oldest (Historical) prestressed bridges, these bridges appear to have a great deal of excess strength. They are not going to collapse soon; they are in no immediate danger.

Since the strength of prestressed bridges depends on prestressing forces, it appears to be of overriding importance to protect the tendons, through which prestressed forces are applied, from any progressive corrosion. If corrosion is suspected, it would require immediate action to protect the tendons.

Since tendons are generally inaccessible, except where exposed by defects, it is very difficult to detect corrosion or damage to the tendons in ereas not exposed. Such damage in all probability is present but covered up by concrete. Often it is assumed that sound concrete will hide corrosion defects which however are probably less severe than the corrosion defects visible in an exposed area.

This removes the urgency of immediate action to arrest further corrosion and allows time for study to find the most cost effective way of arresting the condition since repair/restoration in most instances becomes impractical.

What should be done?

My recommendation is that distressed structures be reanalyzed using various assumptions of deficiences of tendons including an assumed rate of deterioration. In order to compensate for the occasionally obsolete practices used, allowances must then be made for construction practices, design philosophies, acceptance practices, and materials fabrication techniques used at the time the bridge was designed and fabricated.

This forces the engineer into the unaccustomed position of being a bridge historian and also to be a detective skilled in ferreting out old reports, standards, practices and documents, and into discovering the unpleasant ommissions or to define the reasons which led to distress. Such ommissions if in existance at the time of design, fabrication or construction, would rather be forgotten by the principals especially if they did not clearly report those ommissions at the time when they occured.

All of this has to be considered when making a final decision as to what should be done to provide an answer to some of the basic questions:

Is the bridge adequate for the current design load?

If not adequate, should the bridge be posted?

If in need of posting, for how much?

If inadequate, shall the bridge be closed or dismantled and how soon?

For the Walnut Lane Bridge, this question was answered at that time by Stress Analysis, Installation of deflection/camber "tattle tales" (deflection indicators), Simple Load Test, and the application of repair methods which extended the life of the structure.

Such a method is shown in the following slides:

A follow-up inspection in 1970 (16) showed no new cracks. Subsequent inspections and two additional inspections made by myself in cooperation with the District Bridge Engineer's Office as late as 1977 showed some small new cracks and opening of some old cracks.

For the Walnut Lane Bridge, the injection was generally successful. The loose unreinforced concrete shown in Fig. 4 stayed glued together. The tendon ducts were sealed from further corrosion. However, some cracks had to be reinjected and some of the epoxy did not harden completely. The progressively increasing girder cracking was slowed down considerably. I witnessed some of the reinjection of those cracks by the original epoxy injection contractor, which was done free of charge.

When inspecting the bridge, the writer recalls that it was virtually impossible to properly inspect the strands even at some areas where the bottom of a wire tendon was exposed. Some corrosion was apparent. Rust was dark with some scaling evident. Also the epoxy injectors, and the repair contractor's engineer observed and reported some water seepage present in cracks apparently leading to the ducts. It appeared that water seeped through the superstructure joints and was then running along the end face of the beam. It is this writer's hypothesis that some of the deck expansion joints leaked water onto the end face of the beam. This water then penetrated through the end anchorage grout patches and leaked into the duct. This is an assumption, since close visual inspection of the end face, including probing beyond the sound concrete surfaces, was impossible.

The Hershey Bridge Beam (slides 15 to 17) has not been repaired at all and this writer did note progressive corrosion in the strands exposed by the wide cracks but feels that mortar or epoxy sealing in this instance would be a cosmetic procedure and would not protect the tendons properly unless the beam is pressure-injected with epoxy through-out and the voids are packed with epoxy mortar.

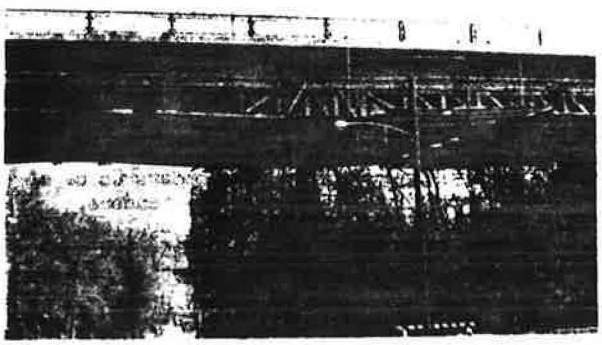
For other box beams showing damages similar to slides 18 through 20, a surface coating of sealer for all exposed surfaces of undamaged beams plus epoxy coating for the exposed strands (after sand blasting or - power brush cleaning) is recommended, preceded by a stress analysis of the defective bridge to determine if damaged member is not overstressed under current design criteria. The result of such a stress analysis should be favorable and therefore generally supporting a decision to determine if the sealing is cost effective. When compared with the estimated remaining life of the sealed member as compared with replacement cost.

Cosmetic patching is generally not recommended since it may hide further progressive deterioration.

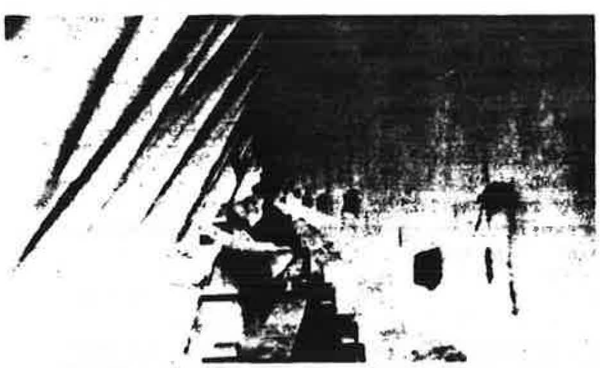
There is a word of caution, however. Increasingly in the literature, there are reports about bridge restoration through epoxy injection.

This writer feels that all that can be done is to treat such a structure to slow down its deterioration. The structure cannot be strengthened by cosmetic patching no matter what "wonder" compound may be used. Pressure injection (one system can inject cracks down to .0076 cm (.003 in.) width) is a good method to seal cracks and perhaps to glue some pieces together, but this process is limited by one's ability to properly clean and surface-prepare narrow existing cracks and is, to some extent limited by the care with which the materials have to be field mixed and injected; and further, restricted by the constraints of weather, humidity and temperature.

Slide 20. Enclosure for epoxy sealing - Walnut Lane Bridge.



Slide 21. Inside enclosure - view of outside face of fascia beam



Slide 22. Pressure injection of epoxy.

It is very encouraging that only very few examples of distress in old bridges can be found. These distresses currently are overshadowed by vehicle-caused defects. Typical examples are shown in the following slides.

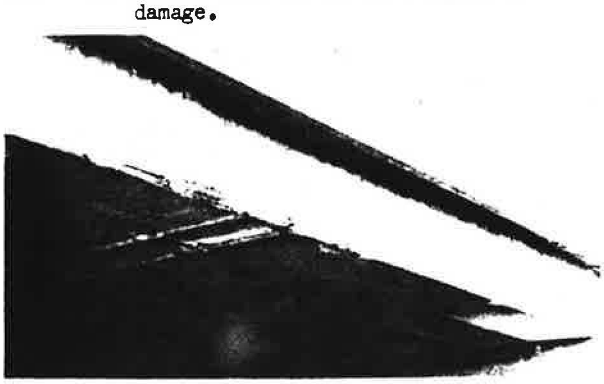
After appropriate stress analysis it was determined that for the box beam bridges cosmetic repairs were all that was required. Cracks were sealed, exposed strands received protective coating and holes were patched.

Similar damage to a prestressed I-beam bridge are shown on the following three slides.

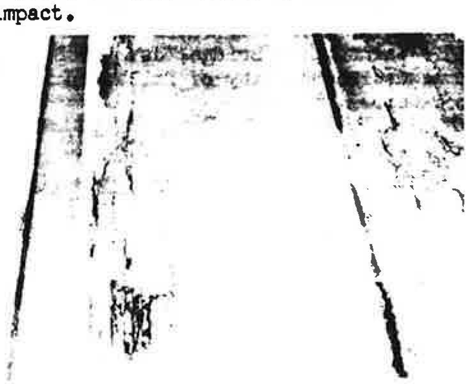
The same procedure was deemed acceptable for the I-beam bridge. Cosmetic repair for the fascia beam was not considered feasible and therefore it was determined to replace the fascia beam in its entirety.

Slide 23. General view of traffice damage to a prestressed concrete adjacent box beam superstructure.

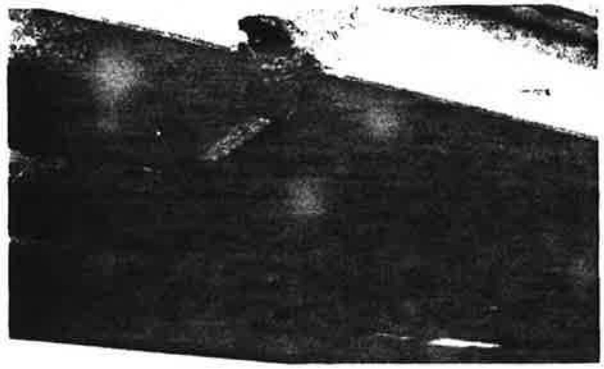
Slide 24. Closer view of the traffic caused damage.



Slide 25. Closeup of the shattered concrete and exposed strands caused by traffic impact.



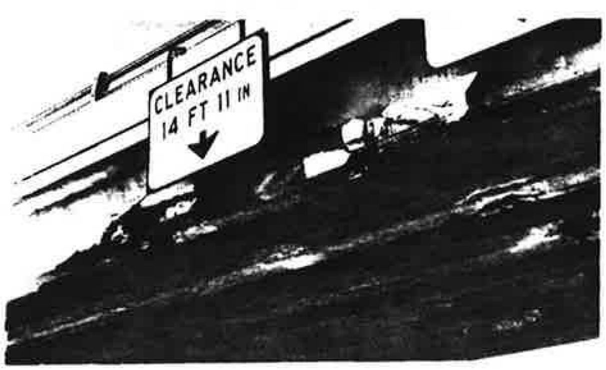
Slide 26. General view of traffic damage to a prestressed concrete spread box beam superstructure.



Slide 27. Closeup of damage and ruptured strands.

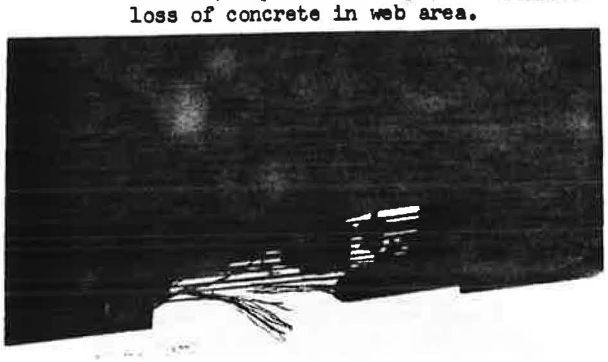
Slide 28. Detailed closeup showing also the cardboard void inside the box beam.

Slide 29. General view of repeated traffic damage to a prestressed I-beam superstructure.



Slide 30. Inside view of the same damage, showing exposed strands and shattered concrete.

Slide 31. Closeup of the damage, showing ruptured strands, exposed stirrups, and complete loss of concrete in web area.



Conclusions - Recommendations

Design

Designs originally were very conservative and further backed up by successful load testing of full scale bridge members. New bridge systems must be very conservatively designed since effect of wear and tear on structure caused by loads, environment and unanticipated factors cannot be readily envisioned at time of initial design.

Construction

Construction techniques must be completely assessed and compatible with the intent of the design. Any aspects of construction procedures which could in one way or another affect the durability of a structure should be identified and replaced with more compatible procedures.

Repair-Maintenance

It must be recognized that prestressed bridges are difficult to repair. The best repair method would require a complete "unloading" of the bridge utilizing jacking or other methods which introduce a reversal of camber (unloading of prestressed moment).

Replacement of tendons is virtually impossible. However, effects of "Lost" tendons can be compensated for, in some cases, by the application of sophisticated external post tensioning.

Considering the inherent difficulty in applying any effective structural repair, cosmetic repairs are often applied but they should be identified as such.

This then leaves maintenance as the only effective means to protect prestressed bridges. However because of the difficulty to repair such bridges properly the maintenance must be really preventive maintenance. In order to avoid wasting maintenance money, preventive maintenance should be applied selectively with regard to type and extent of work on areas of prestressed bridges which can be identified by an engineer thoroughly familiar with past and current prestressed bridge design and fabrication practices.

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