

MATES

MICHIGAN DEPARTMENT OF TRANSPORTATION



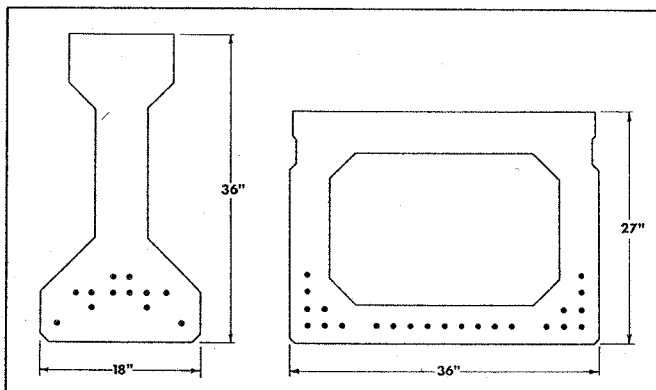
Issue No. 49

December 1990

MICHIGAN'S EXPERIENCE WITH PRESTRESSED CONCRETE BRIDGES

If motorists were to take the time to look upward while driving Michigan's highways, they would notice that bridge beams are constructed of either structural steel or concrete. In order to provide sufficient bending strength, most concrete beams are 'prestressed,' which is accomplished by stretching strands of high strength steel wire between the two end supports of a form and then placing concrete around the strands. After the concrete has cured sufficiently, the strands are released and the concrete, which has bonded to the strands, is placed under compression as the strands attempt to return to their original lengths. As the beam is loaded in service by the traffic crossing the bridge, the design allows the concrete to stay in compression, and the tensile load is carried by the steel strands.

Prestressed concrete construction was first used in the U.S. in the late 1940s, and in 1954 MDOT started using this new technology. MDOT is responsible for about 4,500 bridges and 626 of them are of prestressed concrete construction. The two most common types of prestressed beams used by the Department are I-beams and box beams.



Cross-sections of a typical I-beam (left) and box beam, showing prestressing strands (heights of beams vary, depending on the structure's size).

Because of the size and shape of their cross-section, I-beams can be cast of solid concrete; solid box beams, however, would be too heavy to be practical. Therefore, when fabricating box beams, lightweight blockouts (styrofoam 'void boxes') are placed at intervals within the form, making hollow areas in the beams.

Present Concerns

The majority of prestressed concrete structures, using both box and I-beams, were built during the heyday of Interstate construction. Most of these structures are now over 20 years old, and highway engineers are trying to anticipate the types of deterioration that can be expected from aging in a highway environment. Although not seen as a problem yet, corrosion of the prestressing strands due to intrusion of road salts is one of the most serious potential problems facing our concrete beam bridges. Such corrosion is very difficult to detect. Presently, only 'destructive' methods

are available to accurately determine the extent of corrosion in prestressing strands. That is, a beam must actually be removed and dismantled in order to inspect the condition of the strands. In the near future there is hope that 'non-destructive' test methods will be developed. Ideally, the non-destructive methods would be capable of detecting structural damage and the corrosion activity rate within the prestressing strands. Presently, no non-destructive test method is available for determining both existing damage and corrosion rate. The magnetic field disturbance, and acoustic emission methods presently are capable of detecting structural damage. Other methods now under development show promise for providing corrosion rate results in the near future.

Current MDOT Research

In 1984, the Structural Research Unit of the Materials and Technology Division embarked upon a research project to: 1) evaluate the overall condition of the prestressed concrete bridge population in Michigan; 2) determine the salt content of the concrete at the level of the steel prestressing strands on several representative structures (salt from deicing chemicals accelerates the rusting of the steel); and, 3) inspect a sampling of the entire statewide concrete beam bridge population. This project is being conducted in three phases, two of which have been completed.

The first phase involved a comprehensive search to determine the status of present research in this area by other agencies. Research by other agencies can be summarized by the following general statements:

- 1) The majority of reported cases of strand corrosion involved unbonded (greased and paper wrapped strands) post-tensioned construction (particularly parking garage decks). Grouting the enclosed strands in plastic or metal sheathing significantly improved the behavior of the strands, provided the strands were grouted properly.
- 2) In field studies, no cases of corrosion of properly grouted strands had been reported.
- 3) In two recent studies, strands removed from prestressed I-beams which had been in service for more than 20 years showed very limited strand deterioration.
- 4) In prestressed concrete construction, especially box beams, incidence of steel strand corrosion and concrete deterioration have generally been related to improperly designed drainage details and cracking of the bridge deck surface.
- 5) Once the prestressing strand begins to corrode, unless the strand is thoroughly cleaned, any method to repair the delaminated concrete will prove ineffective.

In the second phase, salvaged box and I-beams from several construction projects were subjected to destructive testing. The beams were photographed and visually evaluated and all staining and cracking were categorized. Concrete samples taken for chloride analysis at the level of the steel strands were also obtained at various locations. The steel strands were removed from the beams and visually inspected to determine their overall condition, and any deterioration was noted. At present, only two methods are available

to determine the cross-sectional loss of strand material due to corrosion. One of the methods, weight loss, could not be used as the original weights of the strands were not known. The other method involves pulling the strands apart in tension to determine tensile strength. If an abrupt difference in the physical condition of a portion of strand was noted, a piece was removed at that location and its tensile strength was compared with that of another piece where the strand was in good physical condition.

Overall condition of a select group of concrete beam bridges was also determined during phase two. Seven box beam and five I-beam structures were subjected to intensive inspections. Five of the seven box beam structures included in this investigation are among the earliest prestressed concrete beam bridges built in the state. Four of the box beam structures carry county roads over rivers and the other three are on the Interstate system. These selections were made to compare the condition of the structures in these two environments.

The beams of each bridge were visually inspected and notes were made of all cracking, spalling, and staining. Spans over water were generally inaccessible, and could not be closely inspected. The condition of the deck of each inspected bridge was also recorded. Decks were examined for evidence of cracking, especially cracking over the longitudinal joints between box beams. If cracking was observed, its type, size and orientation were carefully plotted. Every structure inspected was well documented with slides and a video recording for future reference. Also during this phase, samples of concrete were taken at predetermined locations on each structure for laboratory determination of the amount of water soluble chloride at each level of prestressing strands.

Current Research Findings

Now that phase two of the three-phase program has been completed, it can be concluded that the prestressed concrete beams are in good condition. Any deterioration detected on these beams is of relatively minor magnitude. The following observations can be made about the overall condition of the prestressed box and I-beams in Michigan.

1) Four of the five I-beam bridges inspected were built in 1962. Five of the seven box beam structures inspected were built in 1971. No correlation between the age and deterioration of the structures could be established.

2) For structures of the same age, a relationship was established between the average daily traffic (ADT) and the amount of deterioration found on the structure. The higher the ADT, the greater was the structure's deterioration.

3) All the steel strands removed were from structures carrying local traffic. The data indicate that steel strand removed from a 23 year old I-beam were in better condition than those removed from the 14 year old box beams.

4) The box beams on the county structures carrying local traffic are in better condition than those on the Interstate structures, with the latter showing more cracking and staining.

5) No longitudinal or transverse stress cracking was observed on the county box beam structures. However, we are aware of examples of serious cracking problems on county structures outside of this study sample. A few of the box beams on the Interstate structures showed evidence of limited longitudinal cracks in the beams which were not localized in any particular area. None of these cracks are of significance structurally.

6) The ends of the box beams on all structures exhibited much greater deterioration than the midspan areas. This

is the result of the salt-laden water leaking from the joints over the supports, resulting in higher chloride contents and consequently more deterioration of box beams near the supports.

7) Like the box beams, the ends of the I-beams showed more deterioration. On the majority of the I-beam structures, limited concrete delamination and spalling were observed at the beam ends.

8) All the box beam structures were over rivers or railroads, so the effect of traffic spray from below on the chloride content of box beams could not be determined.

9) Inspection of prestressed I-beam structures at this time did not indicate that the beams over the traffic lanes contained any additional visually discernable deterioration due to traffic spray. However, the traffic flow did have an effect on the chloride content of the prestressed I-beam structures. The traffic-sprayed beams had higher chloride contents.

10) Water staining between adjoining box beams was more visible on Interstate structures. Almost no water stains were found on the county structures.

11) On six out of the seven box beam structures, longitudinal cracks were observed on the bridge deck between the fascia beams and the first interior beams and between the first and the second interior beams. In several cases these beams are under the shoulders of the roadway and not subjected directly to wheel loads. This may cause unequal deflection between these beams and the beams that are subjected directly to wheel loads and may have led to longitudinal cracking. Outer beams also are stiffened by sidewalks and railings in many cases. The longitudinal cracks increased the rate of water flow through the bridge deck.

12) Four out of the five I-beam structures inspected were nine years older than the box beam bridges. The I-beams were in much better condition than the box beams but the average amount of chloride content per cubic yard was higher in all the I-beams than in the box beams. This may be due to the fact that all the I-beam structures were on Interstate highways, whereas the majority of the box beams were on the county bridges, thus receiving lighter applications of chemical deicer.

13) A prestressed I-beam structure inspected in metropolitan Detroit, built during the same year (1962) as most of the other I-beam structures was in far worse condition than I-beam structures in rural locations. This may be due to heavier applications of salt deicer in the Detroit area.

Future Research

The third phase of the project will begin in the spring of 1991. An additional 40 structures will be visually inspected for their overall condition. The selected structures were picked because their conditions were the poorest in the state. Visual inspection of the known deficient areas of the beams may provide us with additional valuable information.

Once this study is completed it will provide design, maintenance, and research engineers with valuable information about the present condition of the prestressed concrete beams. Additionally, engineers and researchers in Michigan and across the nation will be provided with more detailed information about the behavior of prestressed concrete structures and the rate of salt accumulation in them. In the end, this will lead to better designed and constructed structures requiring less maintenance and enjoying a longer life.

-Sonny Jadun