Renovation of the Third Avenue Bridge in Minneapolis

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ABSTRACT

The Third Avenue Bridge has the most dramatic setting and sophisticated design of all Minneapolis spans over the Mississippi. Built in 1918 this reinforced concrete structure had deteriorated to the point where it needed major renovation or replacement. Howard, Needles, Tammen, & Bergendoff, Architects, Engineers, and Planners, did a detailed inspection and evaluation of the bridge. They recommended replacement of the entire deck including roadway, barriers, sidewalks, railings, and lights; the spandrel caps and the upper portions of the spandrels; the entire approach spans, including the bents; and even the abutments and wing walls. Special challenges for the designers included estimating quantities and defining how much of the structure was to be replaced, improving sight distances, improving drainage by inducing a slight grade, protecting the top reinforcement, adding a new safety-shaped barrier between the roadway and the walkways, and developing special provisions for the use of shotcrete. In addition, the designers worked to preserve the historic and aesthetic values of the bridge. It became clear that a normal construction pace would not be acceptable. The bridge was too important to the traffic system to be closed any longer than really necessary. An incentive clause was added to the contract. Construction brought additional problems. The condition of the bridge was worse than expected. Decisions about the extent of the repairs had to be made daily. Nevertheless, the project was a success. The Third Avenue Bridge was reopened to traffic almost a year ahead of schedule and has been saved for decades to come.

The Third Avenue Bridge is one of eleven bridges (or bridge systems) crossing the 9-mile course of the Mississippi River through Minneapolis and connecting the east and west sides of the city. It carries State Highway 65 over the river and connects Third Avenue South on the west (downtown) side to Central Avenue on the east side of the river. These are both major city streets that carry high volumes of traffic.

Of all Minneapolis spans over the Mississippi, the Third Avenue Bridge has the most dramatic setting and sophisticated design (Figure 1). It angles across the river, just above Saint Anthony Falls, on seven low arches that are curved at each end and leads straight into downtown Minneapolis.

Built in 1918 at a cost of $850,000, this reinforced concrete structure had deteriorated badly over the years. The Minnesota Department of Transportation (Mn/DOT) thoroughly renovated the bridge between 1979 and 1981. Because the bridge was in a historic district, was itself a historic structure, spanned a developing park, and had obvious historic and aesthetic values, its renovation posed both special problems and opportunities.

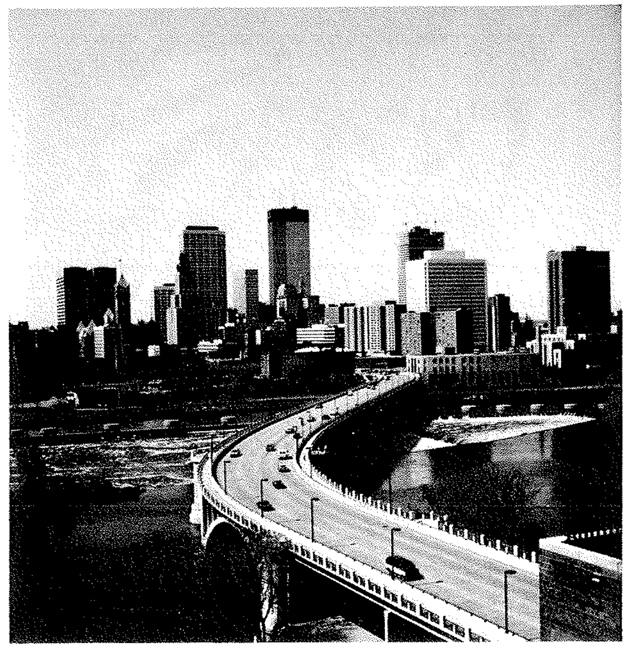

FIGURE 1 Third Avenue Bridge.

The Third Avenue Bridge, 1,864 ft long and 52 ft above the river, was built with four traffic lanes, two broad sidewalks, observation decks, and a spiral stair between the deck and Main Street, below. By the 1960s the bridge had deteriorated to the point where it needed major renovation or replacement. The concrete deck and sidewalks were disintegrating; the east abutment was split top-to-bottom; the spiral stair was a complete ruin.

As originally constructed between 1915 and 1918, the bridge consisted of six distinct units: the southwest abutment, four southwest approach spans over railroad tracks, five ribbed arch spans and two barrel arch spans over the water, four northeast approach spans over another track and Main Street, and the northeast abutment. The earth-filled abutments had reinforced concrete wing walls and abutment walls. Two of the southwest approach spans had sixteen reinforced concrete girders supported by three-column, reinforced concrete bents, and the other two had five steel girders supported by the same type of bents. The five ribbed arches had a clear distance between springing lines of 211 ft; the two barrel arches had a clear distance of 134 ft between springing lines. Open-spandrel columns were used above the ribbed arches, and spandrel walls were used above the barrel arches to support the deck. The four spans of the north approach had sixteen reinforced concrete girders supported by five-column reinforced concrete bents.

The asphalt-surfaced roadway was 56 ft wide between the faces of the traffic railings and was flanked on both sides by concrete sidewalks 9 ft 8 in. wide. The outer railings were decorative art-deco castings, added in 1939. The out-to-out width of the bridge was 82 ft 6 in.

The Third Avenue Bridge was added to the Minnesota Trunk Highway system in 1933 and now carries State Highway 65. The bridge is currently maintained by the city of Minneapolis through an agreement with, and at the expense of, the Minnesota Department of Transportation.

DESIGN

In 1967 Howard, Needles, Tammen, & Bergendoff (HNTB), Architects, Engineers, and Planners, was retained by the Minnesota Highway Department, the predecessor of Mn/DOT, to inspect the Third Avenue Bridge and conduct preliminary engineering for its rehabilitation. They found that localized and progressive failures could occur unless the deterioration was checked.

From the deck the bridge appeared to be in fair condition at that time. The in-depth investigation revealed that the concrete throughout the bridge had areas of severe spalling, which often exposed the reinforcement. Mineral deposits and scaling existed in areas where water had seeped through the concrete. These deposits were densest around the deck expansion devices and floor drains.

The corrosive action of locomotive exhausts had deteriorated the concrete beams and steel plate girders in the approach spans, significantly reducing their load carrying capabilities. Additional supporting members had been placed adjacent to the beams in both of the weakened approaches to reinforce them. The structural integrity of the bridge was also diminished by penetrating cracks in the cap beams of the concrete bents, in the spandrel columns and walls, and in the north abutment.

The remaining portions of the bridge were found to be in good general condition. These included the piers and their foundations, the arches, and portions of the spandrel columns and walls. Reconstruction would allow a substantial portion of the bridge to be saved at a cost considerably less than that of building a new bridge. In fact building a new bridge at the same location would have been impractical and perhaps impossible. The existing bridge stands on a thin limestone shelf and is carefully aligned to avoid several large breaks in that shelf. Demolition of the existing bridge would probably further damage the limestone shelf and render it unsuitable as a foundation for any new bridge.

In 1973 HNTB began the reconstruction plans for the Third Avenue Bridge. The designers made plans for a new deck. Drainage was to be improved by inducing a slight grade on the new deck and sidewalk. Neoprene expansion devices were to be used to help prevent deterioration of the concrete around the expansion joints. A type-J safety barrier was to be added to replace the existing tubular steel safety rail between the sidewalks and the traffic lanes. A concrete parapet and a new lighting system were proposed to replace the existing art-deco railing and lighting system.

Improvements below the deck were to include repairing or replacing the spandrel walls and columns. During the inspection, cracks and spalling had been found in the spandrels, but further investigation would be required to determine the full effect these had on the structural integrity of the spandrels. For this reason the plans specified that decisions on the extent to which the spandrels were to be replaced were to be made in the field during reconstruction.

The new design called for completely rebuilding both abutments and approach spans. Because of new design standards, the plans called for replacing the three bents at each approach with single bents of similar design (Figure 2). This was more economical

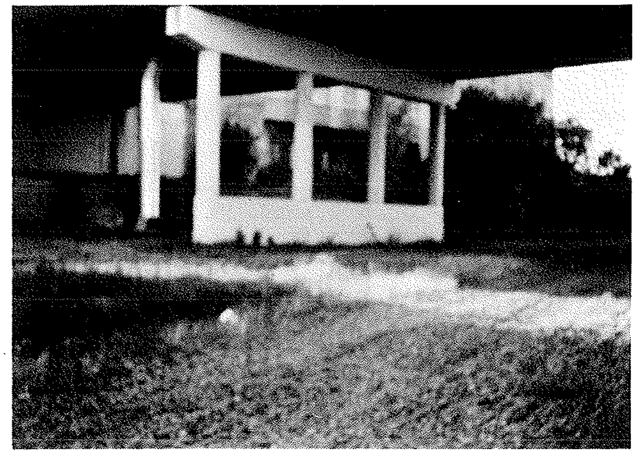

FIGURE 2 South approach bent.

than the three-bent design, and opened the space beneath the bridge. In addition, a 36-in.-diameter water main was to be added beneath the deck.

The plans called for extensive use of shotcrete to repair the spalling and cracking concrete found throughout the structure. Quantities of shotcrete to be used were estimated in the plans but were to be finally determined in the field. The bridge was then to be coated in Thoroseal to give it an even color and texture. HNTB submitted the designs to the state for final approval in 1976.

Because the bridge was located in the Saint Anthony Falls Historic District and was itself of considerable historic and aesthetic value, Mn/DOT worked closely with two historical agencies to retain these values. When the Minnesota Historical Society and the Minneapolis Heritage Preservation Commission first reviewed the plans, they were concerned about some aspects of the proposed modernization. The original reconstruction plans were done with economy and function as primary considerations, and they were done to the standards of AASHTO and the bridge specifications of Mn/DOT. The plans did not include reconstruction of the spiral staircase, which had been closed for years and removed in 1976. The historical agencies wanted the stairway replaced. They believed that the stairway was a historic and aesthetic element of the bridge and that pedestrian access from the bridge to the newly redeveloped Main Street area below was essential.

Research of the old plans indicated that a redesign of the old stairway would not meet current safety codes. The spiral radius was too tight to meet today's standards. Redesign using a larger radius would require the purchase of additional right-of-way. The alternative finally agreed upon by all parties was a winding staircase of poured concrete with four straight runs and three round landings, all wrapped around a central pier (Figure 3). The design retained much of the sculptural value of the original design but in a safer and more functional form.

Another concern was the bridge lighting system. The original reconstruction plan called for 19 swanneck, standard freeway design, lighting fixtures. The argument was made that this lighting system would not be in character with the design and historic nature of the bridge. The parties concerned finally decided upon 53 architectural-style units, only 20 ft high (Figure 4). This lighting system satisfies functional standards and looks attractive

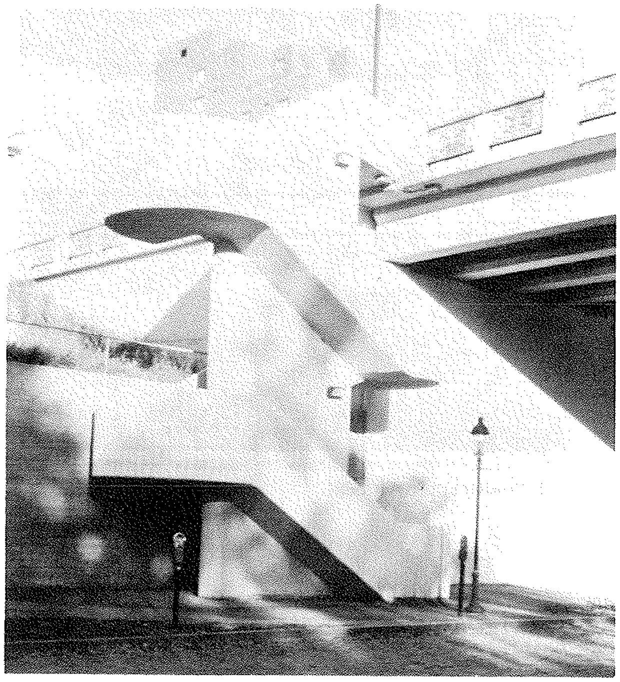

FIGURE 3 Reinforced concrete staircase.

FIGURE 4 Lighting system.

as it outlines the bridge and defines the curves at the ends.

The northeast approach bent was also changed. It was argued that the redesign was less aesthetically pleasing than the original arched bents and that the railroad crash barrier was not needed because the track was used rarely and at slow speeds. A vaulted bent without a crash barrier was finally decided upon (Figure 5). In addition the historic agencies objected to the proposed replacement of the art-deco railing. Mn/DOT agreed that the railing should be salvaged and reinstalled (Figure 6).

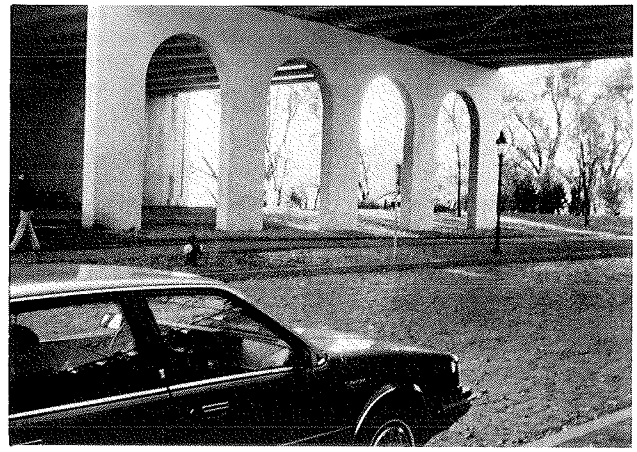

FIGURE 5 North approach to bent.

Before the final plans were submitted in 1979, a few other changes were made. Vehicles approaching the bridge from 1st Street South could not obtain proper sight distances to cross Third Avenue. The vertical profile of the bridge was flattened to alleviate this problem. A flare that widened the bridge at the south approach was also added to the design to improve the sight distance.

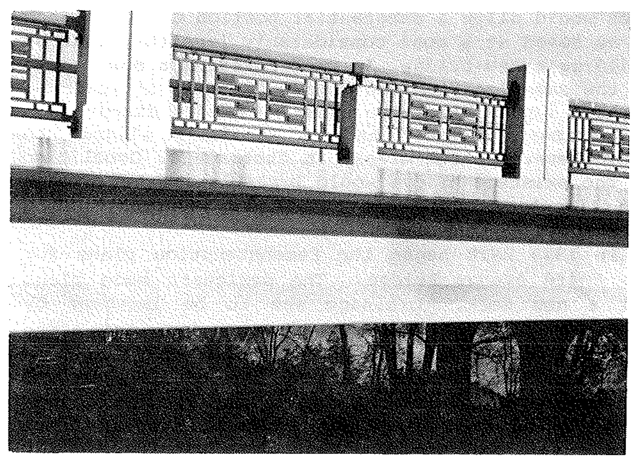

FIGURE 6 Art-deco railing.

Design practices had changed to some extent during the long design period, and the final plan reflected these changes. They included using A588 steel beams in the southwest approach spans and epoxy-coated reinforcing steel and a 2-in. dense concrete wearing course on the roadway of the deck. In addition, the entire reconstruction was redesigned using a load factor.

CONSTRUCTION

The practice of Mn/DOT is to get the construction engineer involved in a project as early as possible.

A field trip was planned well before the final plans were complete to acquaint the field staff with the structure. A "snooper" was scheduled so the substructure could be examined. Unfortunately the sidewalk geometrics were such that use of the snooper would have created a safety problem. Consequently a closeup inspection of the deterioration did not occur until construction began, leaving the extent of the problem a surprise. The more accessible areas were inspected and binoculars were used to view the rest. Another bridge was examined that, several years earlier, had undergone similar repairs, and the engineers and inspectors from that job were interviewed. That input was given to a Mn/DOT design liaison person who, in turn, conveyed it to the consultant. One significant item revised by the field input was the quantity of shotcrete. The initial quantity called for was 50 cubic yards. It was recommended that this be increased to 500 cubic yards. That amount was determined not by measurements but by the combined experience and judgment of field personnel. The actual final quantity came to about 600 cubic yards.

The next task was to determine the number of working days needed to complete the work. That number was to be a stipulation of the contract. Past records were used for production rates. Reports from other agencies gave typical times and production rates. The similar repair project, previously mentioned, was used as a guide. Contractors were called for their ideas. In the end the field personnel sat down with the plans and mapped out how the work would be accomplished and what would be the controlling operation. The fact that Minnesota does not charge working days between November 15 and April 15 was taken into account. Estimates were made of how much work could be done during this "free" time. Also taken into account was the fact that work pursuant to the contract, because of the letting date, could not start until late fall. One important question was how much leeway to allow to accomplish unanticipated repairs. At what point should repairs be stopped and the existing structure used? Another problem was the installation of the new water main; the city of Minneapolis typically prefers to use its own forces. Would that create a coordination problem? Still another problem was to maintain Northwestern Bell telephone service in existing ducts.

After much deliberation, a reasonable number of working days were determined. Taking into consideration the September 15 cutoff date for laying a bituminous wearing course, the October 15 cutoff date for the low-slump concrete deck overlay, and the typical 110 working days in a Minnesota bridge construction season, final completion was projected well into the second construction season.

The district staff was so advised. They in turn consulted with the city of Minneapolis, which determined that a closure of this vital link for that period of time would create a serious negative economic impact on the city. Meetings were held with city officials, the city council, and business associations. The bridge connects downtown with the historic Saint Anthony area (the beginnings of Minneapolis). The area was being redeveloped and the new merchants of the area were concerned that a closure would be devasting to their business. For obvious economic reasons they requested that the bridge not be closed during the first Christmas season.

How could the closure time be held to a minimum? To have a contractor accelerate the schedule would mean more cost to Mn/DOT. How much more was Mn/DOT willing to pay? The date of September 18, 1981, was established as the latest date Mn/DOT wanted to have traffic restored to the structure. An incentive of $5,000 per day, for up to a maximum of 100 calendar days, was offered for early completion. The amount was determined by calculating $3 per hour delay per vehicle, and $0.19 per mile per vehicle for a detour. These figures gave nearly a 2-to-1 benefit-cost ratio. The same amount per day would be assessed as damages if the contractor failed to open the bridge by September 18, 1981.

The contract was written to allow the contractor to use ingenuity in finding ways to earn the incentive. The city council revised a noise ordinance to allow around-the-clock work. The new water main was included in the contract, thus eliminating some possible coordination problems. A stipulation was included in the contract requiring that one lane of traffic be open in each direction until January 2, 1980, thus satisfying the Saint Anthony merchants.

Bids were opened at a special letting on July 6, 1979, and Johnson Brothers Corporation of Litchfield, Minnesota, was the low bidder at $9.1 million. They elected to maintain traffic on the upstream half of the bridge, and bolted portable traffic barriers to the in-place deck (Figure 7). Demolition began with removal of the bituminous surface and the sand layer that was over the structural slab (Figure 8). At that point it became apparent that the structure was in worse shape than anticipated (Figure 9). It was questionable how much construction equipment the slab could support. On the

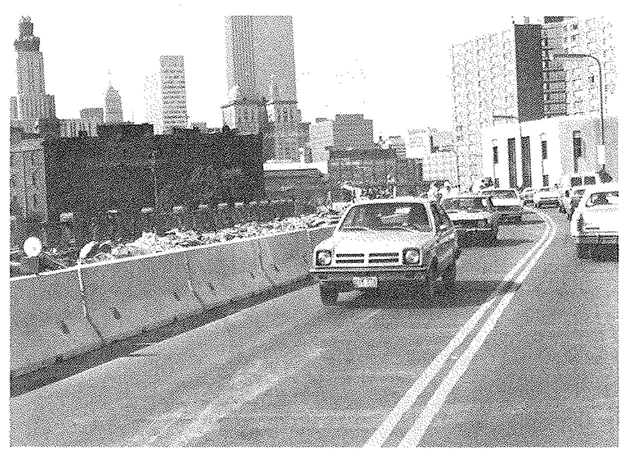

FIGURE 7 Traffic barrier on upstream half of bridge.

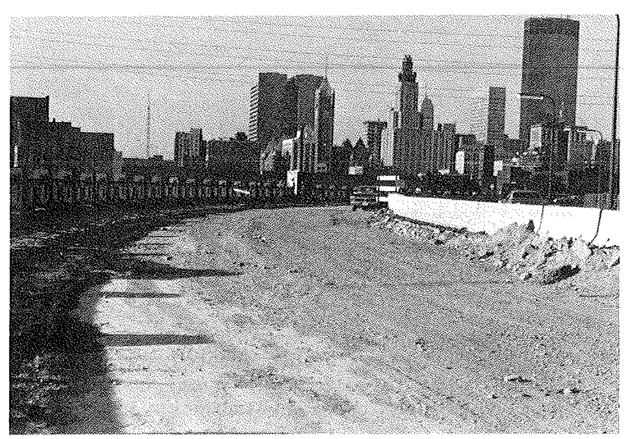

FIGURE 8 Sand layer removed.

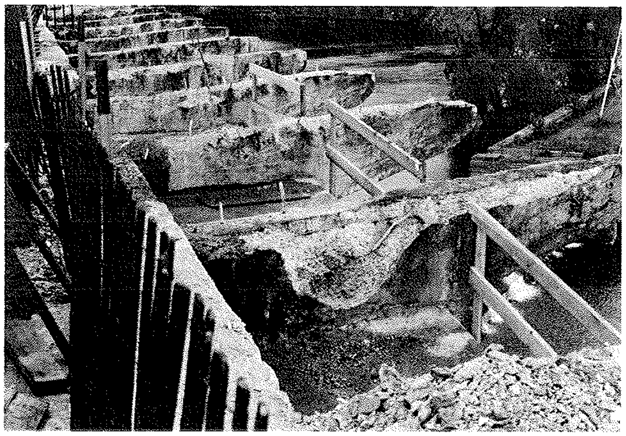

FIGURE 9 Deterioration of cap.

FIGURE 10 Holes in structural slab.

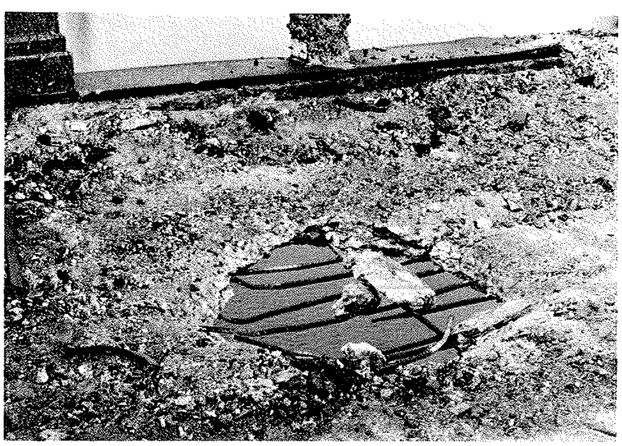

FIGURE 11 Hole opened by tire of front-end loader.

northeast approach spans, which had been underpinned, portions of the slab disintegrated leaving fairly large holes (Figure 10). On one occasion the tire of a front-end loader, which was removing the sand layer, fell through the structural slab (Figure 11). Another question was how the substructure would react to the unloading of just half of the superstructure. The plans suggested that a certain sequence be followed. Experience on a previous project indicated that the sequencing would create no problems. Traffic was still carried on the upstream half, and whether that half would hold up became a concern. In addition to the poor condition of the structural slab, it was found that some of the spandrel columns had deteriorated to the point where they were only half as wide as they should have been (Figure 12). The strength of the remaining concrete was questionable. At that point all trucks and buses were banned. The inspectors were on a continual lookout for signs of fatigue or failure. At one time Ames dials were installed, and it was found that the freeze-thaw in the "punky" concrete was causing it to move but that the movement was not progressive.

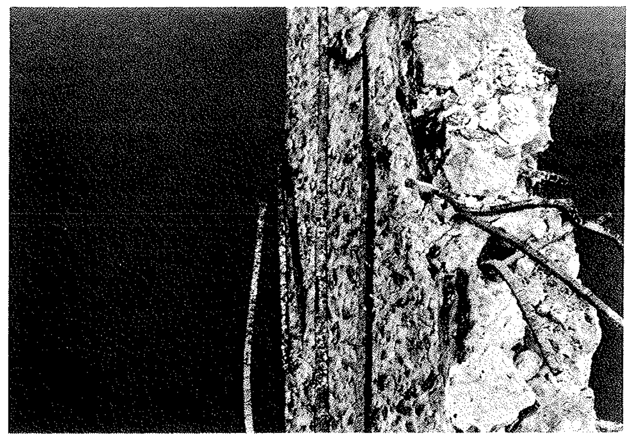

FIGURE 12 Spandrel cap deterioration.

When the sand layer had been removed the contractor began concrete removal. The method chosen to remove the old deck was to first saw it into large panels (Figure 13). The contractor devised a sling-type device that, when used with a mobile crane, held the slab while the reinforcing steel was cut. When the steel was cut the crane merely lifted the slab and set it on waiting trucks or on a spot from which it could be hauled away later. The deteriorated spandrel columns and walls were removed in a

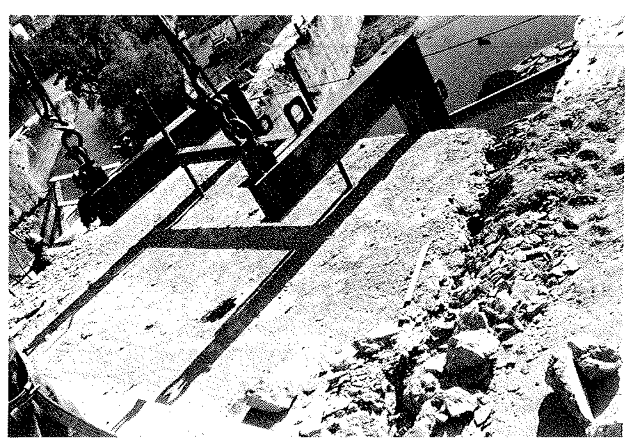

FIGURE 13 Deck removal.

similar way (Figure 14). Holes were drilled at the elevation to be cut, and splitters and torches were used so that large sections could be removed at a time. These methods helped control the rubble problem. The contract stipulated that rubble not be dropped into the river. Immediately after these removals the contractor built a false deck below the elevation of the new deck. This served not only as a replacement for safety nets but as a work platform to increase efficiency and to catch rubble. The removal operations continued around the clock until well into the winter when the contractor determined that the removals were no longer a factor affecting the efficiency of the daytime rebuilding crew.

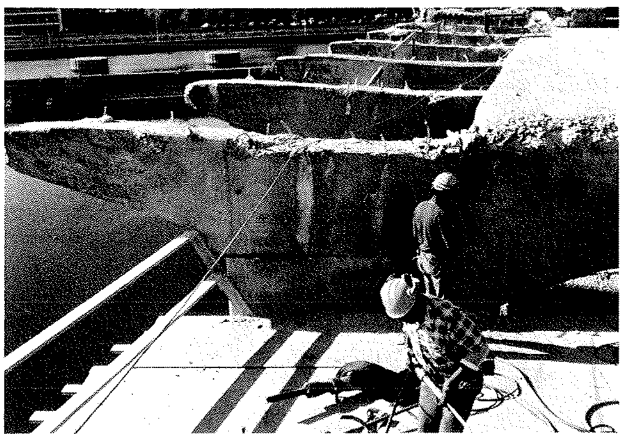

FIGURE 14 Spandrel removal.

Shortly after the bids were opened, the field engineering staff was forced to take a look at the different types of concrete repair. What did the contract say? When should the various types of repair be used? Until then it had not been anticipated that there would be such a drastic difference in the bid unit prices. For instance, the shotcrete was $2,000 per cubic yard; the mortar patch was $500 per cubic yard. Part of the reason some of the repair prices were so high was the specification that removal of unsound concrete be included in the price--jackhammering, chipping, and all the handwork.

One area that was anticipated to be a problem, but was not, was the repair of the spandrel columns. The actual elevation to which they were to be removed was to be determined by the engineer in the field. The method of determining whether the column should be repaired or completely removed and built anew was simple. The length of column and the square footage of shotcrete repair at which the cost would be equal were computed. If the needed shotcrete repair was greater than that, the decision was to remove the column down to the arch. This required inspectors to be on the spot while the demolition was taking place.

The determination was based on the results of visual inspection and sounding with a miner's hammer. This method worked quite well. In only one case was it determined, during subsequent repair, that a column should have been completely removed. The freezing weather during the initial inspection was apparently responsible for the sound appearance of the concrete. The "punky" concrete had been frozen and so had looked and sounded like sound concrete. Just prior to the shotcrete repair a more thorough inspection was made and specific areas were marked for removal. The removal crews were watched to verify the accuracy of the previous findings. Inspection consisted of not only viewing the material being removed but watching the equipment and the workmanship of the crews. It was specified that the removals be done with hammers not heavier than 5 lb. Larger hammers could cause costly and unnecessary damage.

Another area where it was difficult to determine which type of repair to use was the pier repair. The piers near the water line were in quite bad shape. The experience on the spandrel columns showed that the strength of the shotcrete was quite high. Strengths of 8,000 to 9,000 psi were experienced in just a few days. The low-slump concrete used on other deck repairs had given strengths of 6,000+ psi on 28-day tests. Considering that, it was determined that near the waterline shotcrete rather than forming and pouring should be used. The shotcrete method would also give a tighter bond that would be more resistant to freeze-thaw cycles and the water action of the river. During the repair of the piers, in many instances not just a few inches but several feet of bad concrete were removed (Figure 15). The shotcrete was applied in layers as specified.

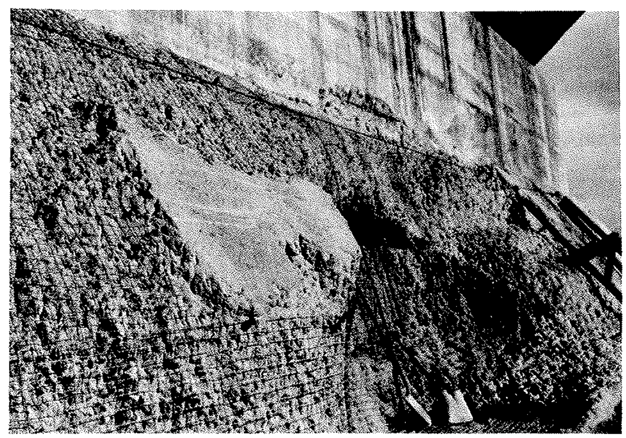

FIGURE 15 Pier repairs before shotcreting.

Mortar patch was to be used primarily on horizontal surfaces. An example of this was repairs on the tops of the arches. In most instances the contractor chose to use shotcrete but to be paid the mortar patch unit price.

The bridge was closed to traffic after the first of the year and the contractor continued work. The approach spans over land at the northeast end of the bridge were completely torn down. The approach spans over land at the southwest end were left in place until nearly the end of the job and were used by the contractor for access. The temporary Northwestern Bell trestle at the northeast end was also used for foot access by workmen. The upstream half of the bridge was used as an access road and not demolished until enough of the downstream half was rebuilt to allow it to be used for access. Except for a short time when the weather was too bitterly cold to work, rebuilding of the spandrel columns and the northeast pier continued all winter (Figure 16). Forms were insulated and the temperature of the concrete was continually checked to be sure that it did not freeze. The first section of structural deck was ready for concrete pouring by April (Figure 17).

During the rebuilding it soon became apparent

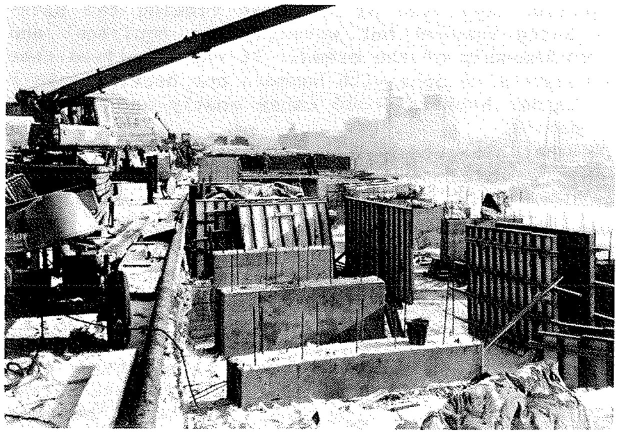

FIGURE 16 Winter work.

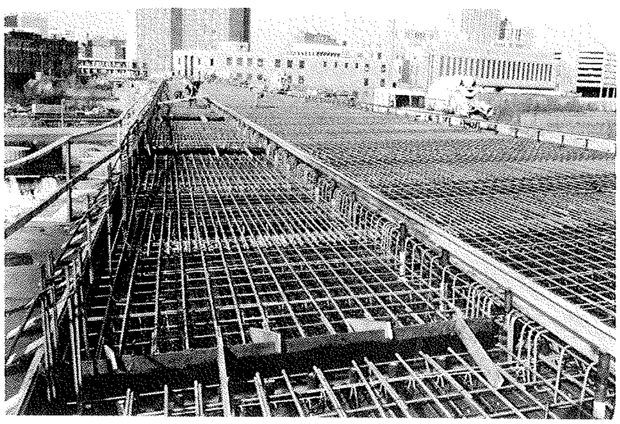

FIGURE 17 Structural deck ready for pouring of concrete.

that the as-built plans did not always represent the actual structure. Dimensions did not always agree. In-place reinforcing steel was not always where shown; in some places it was rusted through or even missing. This created a potential problem because the contractor was working to earn the full incentive. A misrepresentation on the plans, or a failure to make timely decisions, could leave Mn/DOT open to future claims. Luckily a good working relationship between the state and Johnson Brothers had been established. Workers were looking for and reporting potential problems early enough for timely modifications to be made. Mn/DOT and HNTB designers were available when needed for design modifications. Decisions had to be made daily, sometimes at the spur of the moment. Maintaining the intent of the plan and good workmanship were the primary objectives.

Demolition of the upstream half of the structure began after the new structural slab on the downstream half could be used for contractor access. Operations similar to those of the first half, except that no night work was scheduled, continued. The last sections of the structure to be demolished and rebuilt were the approach spans over land at the southwest end of the bridge.

The safety barrier was poured and the low-slump concrete wearing course pavement was placed by the October 1 cutoff date. An unexpected incident occurred during the placement of the low-slump concrete. The arches were contracting during the cool late summer evenings. In some cases the green low-slump concrete debonded before the joints could be sawed. All the joints were then checked for debonding. Where necessary they were cut out and repoured to leave room for temperature-induced movement.

Mn/DOT normally provides all the surveying on its construction projects, but in this case it was specified that the contractor would furnish it. There were two reasons for this: First, inspectors were busy on other projects. Second, with the shortage of manpower Mn/DOT did not want to be in a position of delaying the contractor. It was believed that the contractor should have flexibility and control scheduling if he was trying to earn the incentive.

By fall the art-deco railings, which had been removed before demolition, were reinstalled. The new lighting system was installed and operational. In late November, almost a year ahead of schedule, the bridge was reopened to traffic and the Johnson Brothers Corporation earned the full incentive payment. Work beneath the deck continued until the following summer. That work consisted of finishing the shotcrete repair and refinishing the entire structure to a uniform texture and color. Finally, the new staircase was built.

CONCLUSIONS

Mn/DOT believes that the renovation of the Third Avenue Bridge (Figure 18) was a complete success.

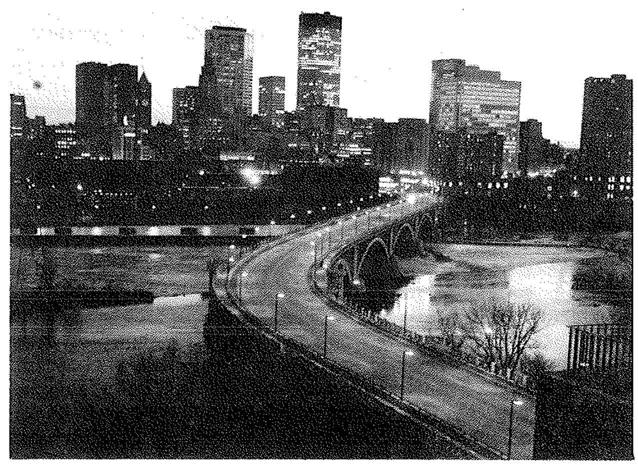

FIGURE 18 Night view of rehabilitated Third Avenue Bridge.

Almost all known renovation methods were used. Portions of the bridge were completely rebuilt. Portions were patched or repaired with shotcrete. New joints were watertight. Epoxy-coated reinforcement bars were used. The upper portion of the deck was low-slump concrete. The latest safety standards were incorporated. The historic and aesthetic integrity of the bridge was maintained. The structure was out of service for less than a year, which was a plus in the eyes of the public. Complete demolition and replacement, even if possible, would have taken several years. The project won a national third-place award from the FHWA for "excellence in design for historic preservation and cultural enhancement." The project was given an award for design excellence by the Minneapolis Committee on Urban Environment. Best of all, the useful and lovely Third Avenue Bridge has been saved for decades to come.

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