

Bridge Repair and Hydrodemolition of Wabash Memorial Toll Bridge, State Road 62

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Introduction: Kenneth R. Hoover, Deputy Director

Bridge deck rehabilitation has become a major project for most highway departments. The overlaying of a bridge deck has become popular because of the economics of prolonging the life of the deck with an overlay rather than with complete replacement.

A good overlay requires that you have knowledge of the existing deck, that you design the overlay, and that you properly prepare the deck so that the overlay will bond to the existing deck and reinforcing steel.

This discussion covers the rehabilitation of the Wabash River Memorial Bridge which crosses the Wabash River seven miles west of Mt. Vernon, Indiana, and connects Indiana State Road 62 with Illinois State Road 141.

This toll bridge was a cooperative effort of the Indiana State Highway Commission, the Indiana Toll Bridge Commission, and the Illinois Department of Public Works and Buildings. The Toll Bridge Commission built the main structure and the Indiana State Highway Commission built the approach spans.

The through truss structure had been overlaid with latex modified concrete in a previous contract; however, the approach spans on the Indiana approach were a real problem. The spans had been overlaid with asphalt and there were indications of distress in the concrete deck. The extent of that distress was not obvious because of the asphalt overlay.

A review of the various repair possibilities was done by Mr. Van Nielen. Consideration was given to traditional deck replacement, deck replacement with prestressed post tensioned sections, etc. Primary concerns were cost, keeping the structure open to traffic, and the least amount of interference with our patrons.

Because of the cost of deck replacement, we decided we needed more information about the existing deck. Mr. Robert Lowry of the Department's Division of Materials and Tests gave us Mr. R.K. Smutzer who provided us with information about the concrete deck from cores.

With the new information about the deck, it was decided that the best approach was a deck overlay rather than replacement. Mr. Van Nielen's research

indicated that the new approach of hydrodemolition should fit our needs. He prepared the special provision for this method of deck preparation. The contractor was Hydro-Technologies Inc., a part of the E.H. Hughes organization specializing in the new technology of hydrodemolition.

Presentation of Richard Smutzer, Division of Materials and Tests

The Division of Materials and Tests was contacted by Mr. Hoover relative to initiating an investigation of the Wabash River Toll Bridge. Mr. Van Nielen and myself discussed the scope of the work and arranged a schedule for the field work. Mr. A.R. Zander prepared the final report.

Since an existing bituminous concrete overlay was on the bridge deck, the chain dragging method could not be used to detect delaminations. After a visual survey of the bituminous concrete overlay surface and the accessible underside of the bridge deck, 52 core locations were selected, 26 cores in each lane. These cores were located in both sound areas and areas of distress, relative to the condition of the overlay's surface:

- 31 cores were located in good areas;
- 10 cores were located over cracked and/or sealed areas; and,
- 11 cores were located in or adjacent to patched areas.

After coring it was revealed that:

- 17 cores were in solid concrete;
- 24 cores exhibited different degrees of delamination; and,
- 11 cores exhibited severe delamination.

Each of the cores was sketched in profile to illustrate their condition.

Compressive strengths were determined on selected cores and indicated an average strength of approximately 6,000 psi with a minimum strength of 4,500 psi.

Hardened concrete air content determinations indicated a range from 2 to 4 percent.

Chloride ion contents in the deck generally exceeded the two pounds per cubic yard corrosion threshold limit at the depth of the upper reinforcing steel.

Examination of the 56 rebars extracted from the 52 cores revealed that the upper steel reinforcement had:

- 18 bars with no corrosion;
- 3 bars with slight corrosion;
- 6 bars which were slightly corroded; and,
- 10 bars which were severely corroded;

whereas the lower steel reinforcement had:

- 11 bars with no corrosion;
- 5 bars with slight corrosion;
- 3 bars which were corroded;
- no bars which were severely corroded.

Rapid chloride ion permeability tests conducted on two cores indicated a chloride ion permeability in the low to moderate range.

In conclusion, the overall condition of the bridge deck appeared to be good and the depth of delaminated areas was generally limited to that of the upper steel reinforcement.

Presentation of Nicholas Van Nielen, Chief, Division of Toll Bridges

The Division of Toll Bridges, Indiana Department of Highways, is accountable and responsible to the Indiana Toll Finance Authority for the administration, operation, and maintenance of the three toll bridges in southern Indiana.

During this past year, the Toll Bridge Division successfully used an innovative technique to rehabilitate the Wabash Memorial Toll Bridge. The state-of-the-art technique was hydrodemolition. This was the first major bridge rehabilitation project in Indiana to exclusively specify the use of hydrodemolition equipment for the removal of deteriorated concrete.

Hydrodemolition is a high pressure water jet which strips away deteriorated concrete without damage to the reinforcing steel and sound concrete associated with the conventional use of jackhammers. High velocity water jets remove deteriorated concrete to whatever depth it is found once the equipment is calibrated to set parameters.

All of us are aware of the wearing force of water. Over eons of geological time, the Colorado River carved the Grand Canyon, and the Niagara River the famous falls.

In the hydrodemolition technique, grooves are cut into the concrete at regular intervals by water jets under some 18,000 psi at 32 gallons per minute per nozzle. Laminated or deteriorated concrete between the grooves is stripped away between the cuts, leaving sound concrete. Reinforced and structural steel elements are exposed and need no subsequent sandblasting.

Just short of 5,000 feet in length with a 26 foot roadway, the Wabash Memorial Toll Bridge was opened to traffic in 1956 at a construction cost of \$3 million. After 30 years of service with a current average daily traffic of 2,700 vehicles, the Wabash Bridge showed signs of deck deterioration. There were two choices: completely remove the deck in place or rehabilitate it.

Replacement of the entire deck would be at an estimated cost of \$7-10 million.

As a point of interest, I was the original bridge construction project engineer on the Indiana approach construction in the mid 1950s. Some 30 years later, I was charged with the responsibility of extending the life of the bridge.

Unlike new construction, rehabilitating a deteriorated major bridge structure involves many unknowns, uncertainties, and risks. Some distress, as I learned, is so well hidden that it is uncovered only after repairs have started.

Our first approach to the rehabilitation project was to rely upon the expertise of the Indiana State Highway Division of Materials and Tests. Much useful information was gained from the core study. No major bridge rehabilitation project ever should be undertaken without first taking concrete core samples that really give you a cross section of the existing deck.

Once the core report was submitted to us, the plan of attack was clear; that is, remove the deteriorated or laminated concrete to at least a depth of one-and-one-half inches below the original deck surface and overlay with a two-inch modified concrete overlay.

The Toll Bridge Division was not satisfied with the conventional method of the removal of deteriorated or delaminated concrete by jackhammering. This method is slow and the depth of sound concrete requires a judgement call by field personnel, which can lead to inconsistent results with excessive concrete breaking

in some instances and insufficient breaking in others. Vibration of the reinforcing steel when struck by jackhammers can cause splitting and weakening of the concrete beyond the edge of the laminations as well as damaging the reinforcing steel. In the conventional method, the deck is usually chaindragged, sounded, and marked prior to removal with jackhammers.

It was our feeling that conventional jackhammering or impact removal fractures the concrete so badly that the bruised layer limits the bonding capacity of an overlay of new concrete to the old.

Latex modified concrete is a very expensive repair material, but only as good as its bond to the old slab. It has been said that bridge deck rehabilitation compares to a dentist's repair of a decayed tooth. A solid foundation is needed before making a repair, otherwise like a tooth, the filling will not remain in place.

It was apparent that we needed an alternate technique that would complete the work fast, remove all deteriorated concrete, and cause the least inconvenience to our bridge patrons translating to the least loss of revenue during construction.

Through trade publications, telephone calls, written correspondence, and consultations with various engineers, equipment manufacturers, material suppliers, contractors, and transportation agencies throughout the country and in Canada, I received much help and guidance.

I cannot say enough for the help and guidance that the following gave me from their experience with bridge rehabilitation: Mr. Bradley C. Lutz, president, Lutz Construction Company, Topeka, Kansas; Mr. Joseph Bradley, representing F.I.P. Hydrodemolisher; Mr. Gary J. Ottman, Hydro-Technologies Inc.; Mr. Kenneth E. Hurst, P.E., Kansas State Bridge Engineer; and, Dow Chemical.

The Division of Toll Bridges utilizes a ten-year bridge management program for debt service, revenue, and maintenance. The Wabash Bridge was scheduled for rehabilitation construction starting in 1987 at an estimated cost of \$3 million.

In late 1986, we decided to utilize hydrodemolition exclusively to remove the deteriorated concrete. Plans and specifications had to be developed to best utilize this new technique, as this was the first project in the state to exclusively specify hydrodemolition.

The rehabilitation plan consisted of the removal of one-and-one-half inches of deteriorated concrete below the original surface area, replacing all finger expansion devices, repairing curbs with pneumatic placement of mortar, replacing damaged steel handrail, and painting and overlaying the deck with a two-inch latex modified concrete overlay. Complete plans and specifications were prepared in-house by the Division of Toll Bridges. There were a few sleepless nights during last January, February, and March in the preparation of the plans and specifications.

Through a highway department letting, a contract was awarded to the E.H. Hughes Company in the amount of \$1,677,647.92 in June, 1987. Contract work began in early July with completion on time in December, 1987.

It was specified that the bridge could not be completely shut down to traffic during construction. Construction was to be done one lane at a time, restricting traffic to one lane by use of flagpersons with radios at both ends of the structure twenty-four hours per day. Traffic and signing was handled as a lump sum item. The traffic control worked out well, with only a twelve- to fifteen-minute delay per lane.

There were three classes of hydrodemolition set up on the 11,994 square yards of concrete deck.

Class I Remove the entire bridge surface one-and-one-half inches deep.

Class II Removal of concrete as directed by engineer equal to three inches. If the equipment cuts below the Class I pass, there would be no pay for Class II removal.

Class III Removal for the total depth of the deck below the limits of Class II as directed by the engineer.

Since the 2,533-foot, eastbound lane of the structure from Pier 16 to abutment 52 showed the greatest distress, we elected to start with this lane first, in early July. The entire lane from one end of the bridge to the other was then restricted to one-lane traffic twenty-four hours per day, employing the use of the westbound lane only.

Standard production rates for the removal of one-and-one-half inches using hydrodemolition equipment is about 216 square feet per hour. On our thirteen-foot lane, this is 16.6 L.F. per hour. Comparing this to a man on a jackhammer at an estimated production rate of about five square feet per hour, it would take 40 jackhammers to do the same amount of work that the hydrodemolisher does.

At first we did not achieve this production rate. This called for some hasty conferences between the equipment manufacturer and contractor before problems were straightened out. It goes without saying that both the contractor and the Toll Bridge Division gained valuable experience on this project.

Based on the experience gained on this rehabilitation project, there are a few bid items that will be changed on future contracts of this nature. Except for minor tune-up, the special provisions need not be altered for our two other anticipated toll bridge rehabilitation projects.

Our construction project engineering was done by Parsons, Brinckerhoff, Quade and Douglas Inc.

The hydro-robot which was programmed to remove a one-and-one-half-inch layer of deteriorated concrete also removed any deteriorated concrete automatically at greater depths. In many areas, the water jets blasted through the entire seven-inch deck in the first pass. When I first observed this, I could see the dollar signs rolling, but in the jackhammer method this deterioration easily could have been overlooked.

The self-propelled mobile unit contains high pressure water jets transversely mounted on a track at the back of the unit. As the robot incrementally advances, the nozzles sweep back and forth, scarifying a series of ribs. Controlled from a remotely located electronic console, the unit can be adjusted to vary the depth of sound concrete to be demolished. The jet water blast then automatically breaks out all deteriorated or delaminated concrete as it penetrates the slab down to the predetermined level of sound concrete. The upper, top layer of the reinforcing steel is fully exposed and clean when the unit has passed. There is no need to go back and sandblast the steel as is done in the impact or jackhammer method. The lower mat of steel usually is fully exposed at points of corrosion and delamination and partially exposed in sound concrete areas. Where there is evidence of corrosion in the bars, there is concrete lamination, visible or not. The hydro-robot finds it.

This project was proof positive that the hydrodemolition method selectively removes deteriorated concrete without hydraulically destroying or fracturing sound concrete. Selective removal eliminates the material that has a lower impact resistance to a high pressure water jet than a certain predetermined value of sound concrete. Of greater importance, selected removal of all deteriorated concrete is automatically detected independently of its thickness.

The exposed deck is undamaged by the removal of the deteriorated concrete and free of fractures. The increased and rough surface area provides a higher bond strength between the old concrete and the new.

In my original special provisions, if one-half of the periphery of a bar was exposed, the concrete adjacent to the bar shall be removed to a depth that will permit new concrete to bond to the entire periphery of the bar so exposed. A minimum of one inch was required by the special provisions.

Upon careful observation of the hydrodemolition results, I soon realized that it was unnecessary to surround the rebar to achieve mechanical bonds. The latex modified concrete overlay will bond to clean steel as well as clean concrete. Therefore, I waived the clearance special provision on this contract. I also approved the use of splice clips to splice reinforcing steel bars based on results obtained from the California Department of Transportation. With number 5 bars, only a three-inch overlap is required to splice rebars. Full strength connections can be made between new and old deformed re-steel bars.

As we discovered, there may still be a small amount of unsound concrete requiring removal after the water jet has passed. These areas were located by sounding with a five-foot long rebar and marking the areas for another pass of the equipment. In some cases, chipping hammers were required.

As an area was prepared by hydrodemolition, cleaned, and accepted, the overlay was placed. If the new expansion devices were not completely in place, the pour should stop five feet either side of the joint for a smooth transition. The entire eastbound lane from the Illinois side to the Indiana side, except for the truss spans, was completed in early September and traffic shifted to the completed lane.

The westbound hydrodemolition began in mid September. Although there was much greater full depth removal in this lane than expected, the westbound work went much faster. Hydrodemolition is fast. The entire structure was opened to two-lane traffic on November 20, 1987, less than five months after beginning construction.

In conclusion, hydrodemolition represents a revolutionary technique in speeding up bridge rehabilitation of major bridge structures at an economical cost. Representatives from several states and the Federal Highway Administration visited our project and were interested in the specifications that the Division of Toll Bridge developed.

Presentation of James P. Hughes, Sales and Marketing Manager, Hydro-Technologies Inc.

Hydrodemolition promises to be a fantastic new technology for many types of concrete removals. If utilized properly, the new technology offers many benefits to be reaped by both the owner and the contractor.

Specification and actual (not variable) quantities will have the most serious impact on quality, cost, and reaping all the benefits this equipment can bring to the market place.

The ability to change how we have traditionally removed concrete, specified removals, and measured and paid for these removals are other obstacles we will have to overcome in the future to properly utilize this new technology.

Owners and contractors are both fearful of change for justifiable reasons. The owner is usually fearful in regards to direct cost and credibility. The contractor is generally fearful because of the cost of the equipment and the possibility that this equipment can significantly reduce variable risk to the owner therefore minimizing profit to the contractor. However, this is a false sense of fear. With time, many owners through experience will specify this equipment and many contractors will own this equipment because it will not be as expensive.

There are many brands of hydrodemolition equipment and there are many ways you can use this equipment to correct problems with a structure, such as:

- 1) removing partial patches to sound concrete;
- 2) removing partial patches below top or bottom mat of reinforcing steel;
- 3) removing from entire surface of structure (1/4", 3/4", 1", 1-1/4", 1-1/2", etc.) to sound concrete;
- 4) removing from entire surface of structure (Class I, Class II, Class III, specifying depths in Classes I and II, removing full depth in Class III);
- 5) removing from entire surface utilizing a scarifier and hydrodemolition equipment, as follows:
 - a) scarify 1/4", 1/2", 3/4", 1", total surface;
 - b) use hydrodemolition to remove 1/4", 1/2", etc., from total surface, and
 - c) pay by cubic yard for anything that comes out below the specifications of (a) and (b) above; or,
- 6) instead of re-decking, remove from entire surface the concrete below entire top mat of reinforcing steel.

The method in item (5) above can be far more economical than some of the others, but caution must be given to whether or not the scarification equipment will cause further damage to your structures. The type of removal in item (6) above was performed recently on 40,000 square feet by two tandem hydrodemolition units in seven days.

There is always a need for using jackhammers to perform minor trim work or work that is inaccessible to the hydrodemolition equipment.

In regards to partial or total surface removals to sound concrete, reinforcing steel continues to be a problem. The following three methods deal with this problem.

- 1) Go completely under the entire area of reinforcing steel with hydrodemolition.
- 2) Trim these areas with jackhammers. Because of vibration, there is a tendency to revert back to an uncontrollable operation.
- 3) Waive the rebar specification when using hydrodemolition and latex modified concrete. A very important question is whether sound concrete is being removed only to achieve rebar clearance. Latex manufacturers feel it is not necessary to remove sound concrete. Concrete

bonds to concrete as long as all the loose concrete is removed and the surface preparation prior to pouring is excellent. Doing so completely solves the rebar problem, further reduces variable risk, lowers cost, and makes the operation extremely fast. Investigate hydrodemolition, and the savings in time and money could be enormous.

When specifying hydrodemolition as an alternative, you will continue to see variable high pricing. The owner simply passes the variable risk to the contractor who in turn passes it to the hydrodemolition subcontractor. This method of pricing encourages a tendency to stay with traditional methods, limiting the benefits this equipment can bring you. Although the owner has better control over what is removed, you still do not have a realistic idea of what the final cost will be.

In regards to this method, there is often a large variance between the contractor's price and the hydrodemolition firm's. (Example: 235,000 square feet sold for \$12.00 per square feet, and the hydrodemolition firm does the work for \$6.00 per square feet.)

Equipment specifications and calibrations are not enough. When using hydrodemolition, it is best to specify exactly what you want the equipment to do. Also, it is sometimes beneficial to change the method of payment.

Knowledge, investigation, decision, and specifications is an excellent format to use when qualifying a potential hydrodemolition project.

- 1) Become knowledgeable as to what this equipment can do. Start with F.I.P. and Atlas Copco equipment (industry leaders).
- 2) Investigate the problems your structure has in regards to delamination, psi strengths, chloride contents, structural steel, etc., through core samples. Make this information available to contractors.
- 3) Make a decision as to which hydrodemolition method you want to use to correct your problem (total surface or partial, depths, etc.).
- 4) Specify what you want to accomplish. (Do not specify types of equipment to be used; the equipment specifications for all brands are non standard.) Specify types of removals, speed (min. of one cys per hour, capable of twenty-four hours per day operation).

The equipment will revolutionize the way we have been removing concrete for the past 30 years. Removing concrete with jackhammers is uncontrollable, labor intense for both the owner and contractor, and there is a high degree of variable risk during the bidding process and field operations. The benefits the equipment can bring you are:

- 1) removal of concrete without damaging reinforcing or structural steel;
- 2) very selective, repeatable results;
- 3) quality, consistent, efficient removal;
- 4) reduction of unknowns, uncertainties, variable risk to the owner and the contractor, if specified properly;
- 5) elimination of excess removal;
- 6) less overlay materials are used to fill the resulting voids;
- 7) less full depth occurrence;
- 8) reduction of noise, elimination of dust;
- 9) superior bondable surfaces;
- 10) twenty-four hour per day operation, day or night, rain or shine;

- 11) drastic reduction in labor forces, and contractor and state supervision can be redirected in other areas;
- 12) reduction in owner and state overhead (union dues, insurance, payroll transcripts, payroll tabulations, expenses, equipment rentals, office rentals, traffic maintenance, etc.);
- 13) reduction of lost user fees and lost income to surrounding project businesses; and,
- 14) owners have control of their removals.

Hydrodemolition equipment has the capability to remove selected increments of concrete and bad concrete in the same pass.

In the future, owners will continue to strive to specify this equipment to eliminate variable risk. Soon owners will know that the total price they received at a bid letting will be the same (no change) when the work is completed.

Today, there are ways to specify, to remove, and to eliminate entirely the variable risk with hydrodemolition equipment.

Conclusion: Kenneth R. Hoover, Deputy Director

This has been a highly successful project using a new technology that we believe will become the predominate bridge deck rehabilitation method. The system is much less labor intensive, much less time consuming, and leaves a much more desirable surface for bonding to the overlay. It requires a more detailed investigation through core samples of the existing deck than is usually done and requires special provisions rather than the traditional specification for jackhammer removal.



Each nozzle for hydrodemolition requires a truck containing a high pressure pump to provide 35 gpm at 17,000 psi.



The slave used to remove concrete has two nozzles that connect to a high pressure pump and move along the front of the slave.



The slave is in action next to curb with protectors to keep removed concrete from being thrown into adjacent traffic.



The finish section is ready for final cleaning; note excellent surface for bonding and clean re-steel.



Finished curb section showing concrete surface for bonding and clean re-steel.