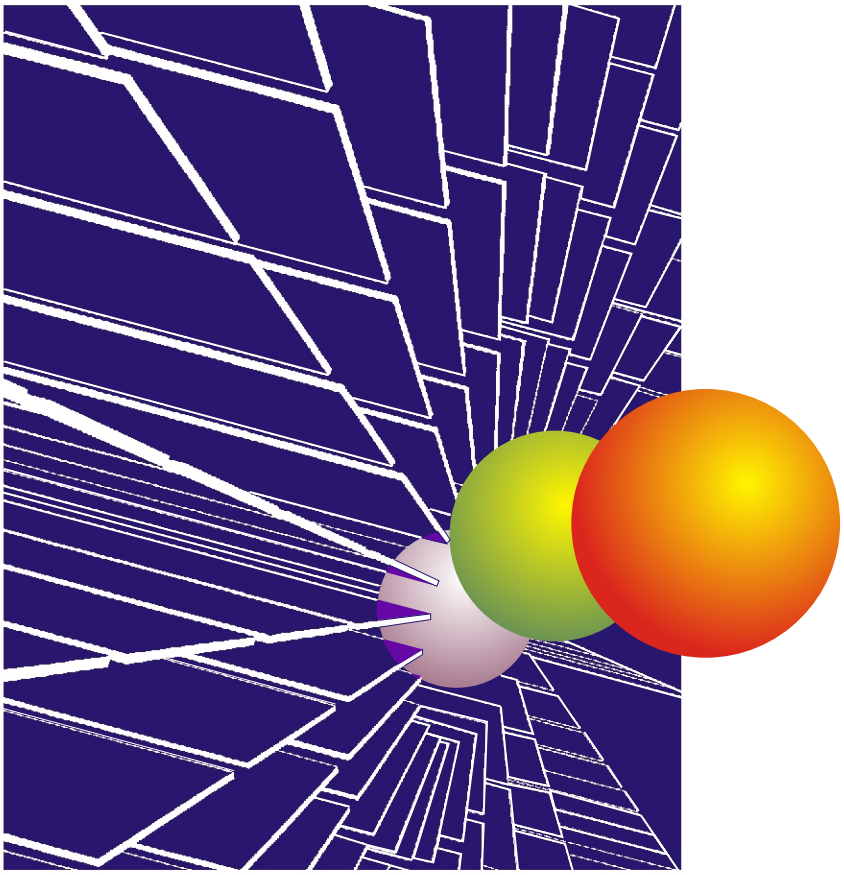
MoDOT

Research, Development and Technology

RDT 02-002

Hydrodemolition and Repair of Bridge Decks

RI 97-025



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16. Abstract The use of modern hydrodemolition equipment for removal of deteriorated concrete and preparation of bridge decks for concrete repair. Comparison of hydrodemolition to conventional sawing and jackhammer removal concerning cost and harm to remaining concrete.		
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RI97-025

Hydrodemolition and Repair of Bridge Decks

Final Report

MISSOURI DEPARTMENT OF TRANSPORTATION
RESEARCH, DEVELOPMENT AND TECHNOLOGY

BY: John D. Wenzlick, P.E.

Acknowledgment to:
Pat Martens, Dave O'Connor

JEFFERSON CITY, MISSOURI
DATE SUBMITTED: December 16, 2002

EXECUTIVE SUMMARY

It was the intent of this study to prove that hydrodemolition is a better alternative to removing deteriorated concrete form bridge decks than conventional mechanical methods such as jackhammers. Jackhammers can cause microfracturing of the concrete left in place. Microfractures in the remaining deck can cause premature loss of bond in the patches or the overlaid surface to which a large investment has been applied in hopes of getting a rehabilitated bridge deck that will last another twenty to thirty years. MoDOT over the past ten years has experienced extensive cracking and debonding of its dense concrete bridge overlays leading to premature deterioration of the rehabilitated decks, well before the end of their design life. Hydrodemolition could help solve these problems in future bridge rehabilitation projects. Additionally, after the hydro-blasted material is removed, hydrodemolition leaves the substrate deck clean, it removes all corrosion from the rebar, and the deck is ready for new concrete to be poured. Additional mechanical cleaning and sandblasting of the concrete surface and rebar is needed with mechanical removal methods. Hydrodemolition has generally been bid cheaper than conventional mechanical methods but is overall more expensive because of mobilization costs and limited availability of hydroblasting equipment and hydrodemolition contractors close to Missouri. Other items like traffic control and staged construction can be an extra cost because it is necessary to have larger areas of bridge deck closed to do hydrodemolition than it is for mechanical methods.

The practices of Missouri's adjoining states were surveyed pertaining to the use of hydrodemolition. Most state specifications use it as an equal alternative to mechanical methods. This study looked at hydrodemolition projects done in Missouri, first by maintenance starting in 1996 in the St. Louis area and continuing on maintenance projects there through 1999. It also looked at the first, and so far only, project designating hydrodemolition as the only method of concrete removal let by construction contract on Route I-44 near Springfield in Green County in 1998. Costs for all the projects done by MoDOT are presented. Costs for hydrodemolition ranged from $ 1.25 to $ 3.50 per square foot ($3.50 bid on the I-44 construction project mentioned above) compared to $ 28.79 to $ 32.99 per square foot for conventional removal. A study of the relative damage done to the concrete left in place was done using direct tension or pull off tests. Generally the testing showed pulloff strengths around 150 psi (pounds per square inch) versus 125 psi for the mechanically prepared concrete. This was not as high as expected since a Swedish study had shown strengths up to 300 psi.

The limited bond testing done did not show large gains in strength over conventional removal but it is believed further testing would show better results. However, hydrodemolition does provide less damage to the remaining concrete and a cleaner surface ready for the patching or overlay concrete to stick to in a third of the time as conventional removal. It is recommended that more maintenance and construction contracts be advertised designating hydrodemolition as the only option for removing deteriorated concrete. It is proposed that, on all bridges that meet the criteria for ease of hydrodemolition, all contracts in 2003 be let specifying hydrodemolition exclusively. (It is estimated this would be about twenty five percent (25%) of bridges contracted to be rehabilitated or widened.) This will foster more availability of this equipment and contractors using it. A report on costs savings and life-cycle costs would be prepared from these 2003 jobs to verify how superior and cost effective hydrodemolition is compared to mechanical methods in ensuring long lasting concrete repairs.

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Introduction and Objectives

Hydrodemolition is a faster, cleaner and better way to remove deteriorated concrete from bridge decks in order to patch or rehabilitate the driving surface. The basic steps in the hydrodemolition of concrete bridge decks are as follows. First scarifying of the original bridge deck is required before hydrodemolition of the surface. Hydrodemolition is done with a computerized, self-propelled robotic machine utilizing a high pressure water jet stream in the range of 15,000 to 20,000 PSI and usually removes all unsound concrete in one pass. If required, hand held high pressure wands or 35 lb. maximum jackhammers shall be used in areas inaccessible to the hydrodemolition equipment. The contractor removes the hydrodemolition debris with vacuum equipment before the debris and water is allowed to dry on the deck surface. The contractor will take steps to prevent damage to existing reinforcing steel and not place wheels from heavy equipment, such as vacuum trucks, on areas where the top layer of slab reinforcement has been left unsupported by the hydrodemolition process. After debris is removed the deck surface and patches and the exposed reinforcing steel is usually clean and ready for concrete placement. MoDOT's Job Special Provision (JSP) allows in areas where removal of unsound concrete does not expose the bottom mat of reinforcing in the deck to be patched with latex modified concrete and placed monolithically with the concrete wearing surface.

The hydrodemolition process allows several steps needed in conventional removal to be eliminated. Sounding and marking of delaminated areas is not necessary because after the hydrodemolition equipment is correctly calibrated it will automatically remove any delaminated or deteriorated concrete. This eliminates the need to saw cut around patching areas as needed with conventional jackhammer methods. Sandblasting of rusty or dirty reinforcing steel is not needed because it is cleaned at the time of hydrodemolition. Because of the very good bonding surface left by the hydrodemolition patches are allowed to be placed, if the bottom reinforcement hasn't been exposed, at the same time as the wearing surface concrete. This step alone eliminates the time and labor needed for a separate patching operation and the time to wait for patches to cure before being able to place the wearing surface. The only additional needs for hydrodemolition are a large water supply and the control of runoff water.

It was intended to prove that hydrodemolition is a more efficient and less destructive method than using jackhammers for removing deteriorated concrete from reinforced concrete bridge decks. In hydrodemolition all the deteriorated concrete is removed, the reinforcing steel is cleaned, and the remaining concrete is not left with micro-fractures as it is when jackhammers are used. MoDOT has had a problem over the last ten years or so with premature failures of rehabilitated bridge decks using dense concrete overlays. There have been problems with excessive cracking and with debonding of the overlay from the original deck concrete. These problems have occurred with all types of overlays, latex modified concrete, low slump concrete and silica fume concrete. Curing of the concrete and other factors are causing the cracking problem, but loss of bond could be alleviated by using hydrodemolition instead of conventional mechanical methods of removing deteriorated concrete. Hydrodemolition is more expensive at this time because of the expense of the equipment and the short supply of contractors doing this kind of work. For this reason mobilization costs are high, however, these costs have come down recently with more equipment being manufactured and more contractors now getting into this type of work.

A review of concrete removal practices of the adjacent states was made. Table 1 below lists the states contacted All the states that specify hydrodemolition, allow either it or conventional mechanical methods except Kansas. If a bridge deck is to receive a concrete overlay, Kansas DOT only allows hydrodemolition. Two of the states don't specify hydrodemolition at all.

Table 1: Hydrodemolition Specifications of Other States

State	Hydrodemolition Specifications
Missouri	*Special Provision if an overlay is involved (includes hydrodemolition as alternate for conventional)*
Kansas	*Specification 724 (hydrodemolition only for bridge overlays)*
Illinois	*In Deck Slab Repair Specification (includes hydrodemolition and conventional both)*
Iowa	*Specification 2413 (includes hydrodemolition and conventional both)*
Arkansas	*Nothing found*
Nebraska	*Does not indicate use of hydrodemolition*

Technical Approach

This study was set up to observe the hydrodemolition process and become more familiar with the equipment and its operation. Through pull-off or direct tension testing before and after removal of the deteriorated concrete and after patching, this study was designed to determine the effectiveness of hydrodemolition over conventional jackhammer methods in leaving a better substrate on which to apply new concrete. Hydrodemolition can reduce micro-fracturing while removing all of the deteriorated concrete. Also price comparisons between the two methods were made using costs from several maintenance projects and also one bridge rehabilitation construction project and previous maintenance and contract work.

Results and Discussion (Evaluation)

Hydrodemolition, Fall 1996

The Missouri Department of Transportation, MoDOT, first tried hydrodemolition for the repair and concrete overlay of a bridge by maintenance contract on St. Mary's Way over I-44 in Franklin County just southwest of St. Louis. (Figure 1) The cost was $ 12,000 for one pass of

the hydroblast machine over the whole bridge, 5,800 square feet, or $ 2.06/sf. This price included vacuuming up the debris and dumped on site. MoDOT maintenance forces were used to haul the rubble away. MoDOT also had to set up straw bail dams to catch the solids in the water before it was allowed to enter the roadway ditch. The effluent was checked by MoDOT to supply information on turbidity to the Missouri Department of Natural Resources to make sure it passed clean water standards.

Figure 1: Hydro machine in action. (Note the rubble in Front, compared to the milled deck behind.)

Figure 2: Note the straw bails covered with burlap at the end of the bridge to filter waste water.

The biggest concern from this first project was about the vacuum truck backing onto the rebar mat and bending it down where concrete was removed below the top mat. The heavy truck (Figure 3) worked all right here. However, if a lot of reinforcing steel is showing, plywood would need to be placed under the truck tires to distribute the load better. Alternately, a hand guided vacuum, or one with a boom (Figure 4), which didn't have to travel over the rebar could be substituted for the truck.

Figure 3: Heavy, self contained vacuum truck .
Note: vacuum nozzle located in front of the rear wheel works very well to pick up debris.

Figure 4: Vacuum truck with hose on boom; can stay off rebar mat but is slower picking up debris.

Hydrodemolition, 1997

A second hydrodemolition project was done again by maintenance contract in the summer of 1997 on Bridge L-896, Franklin County, Rt. 100/I-44 only about a mile from the first bridge. Hydroblasting of 5,800 sf. was done for $ 1.25/sf. or a total price of $ 7250. This bridge received a full concrete overlay like Bridge L-868. It demonstrated that MoDOT could extend the life of a second bridge deck by relatively low cost hydrodemolition and repair with a dense concrete overlay. On both the 1996 bridge and this one, one step in the repair process, pouring concrete patches before overlaying, was also eliminated by pouring the patches and overlay at the same time (a monolithic concrete placement).

Under the same bid, hydrodemolition of unsound concrete and patching of 6 other bridges decks on the aging I-70 corridor in St. Louis was completed in a third of the time of conventional jack hammer repair done by MoDOT maintenance crews. (Figure 5) Prices were bid lump sum for each bridge and depended on the amount of square feet patched, they ranged from $ 1.33 sf. ($ 12/sy.) to $ 8.33/sf. ($ 75/sy.).

Repairing these 7 bridge decks (the complete overlay of Br. L-868 plus patching of 6 others) was done in 20 working days using hydrodemolition. It would have taken 60 days by normal hand methods.

Figure 5: Shows traffic control and containment of blast water while hydroblasting for patches in two center lanes of a four lane bridge.

Hydrodemolition, 1998

In 1998 the first construction contract specifying use of hydrodemolition was let for bridges A01741 E and A01741 W on Route I-44, Greene County near Springfield. This was also MoDOT's first contract allowing a monolithic pour after removal of deteriorated deck with a Latex Modified Concrete overlay. This eliminated the usual patching step in between by filling of excavated areas and overlaying with new concrete at the same time.

Because of staged construction, this project required two mobilizations of the hydrodemolition equipment. The westbound bridge was closed to traffic in 1998. The whole deck of the westbound structure, 7,100 sf., was completed. The hydrodemolition contractor returned in early 1999 to do the 7,100 sf. of the eastbound bridge (Figure 6). Even though two trips were required, it is believed the bid was lower than expected due to being able to hydroblast a fairly large amount of surface each trip. Also, no traffic control was needed since the bridges were shut down to traffic.

Figure 6: Finished hydrodemolition of half (background) of Bridge A0174 E. In the foreground, new latex modified concrete overlay. Note: 2" core holes in the overlay are where pull-off tests for direct tension were taken.

Hydrodemolition 1999

Bridge A-185R Ramp on Route I-70, St. Louis City was shut down due to construction in the area. MoDOT maintenance forces took this opportunity to again use hydrodemolition work to repair this bridge deck. A maintenance contract was let for hydrodemolition. The cost was $29.09/sy ($ 3.23/sf) which compared well with the only construction project MoDOT had let with hydrodemolition, discussed above, which bid at $ 31.50/sy ($ 3.50/sf). Poor concrete and a thin 6 1/2" upper deck on this type box girder bridge made it necessary to make two passes with the hydrodemolition machine set at 13,000 psi. (see Figure 7) One pass at the normal setting of 17,000 – 18,000 psi would have blown through the poor quality concrete. Hydrodemolition makes it easier to regulate than conventional methods with regards to how much concrete is removed when it's necessary to patch and keep open a badly deteriorated deck.

Figure 7: Poor concrete and a thin 61/2" upper deck made it necessary to do hydrodemolition at 13,000 psi . This is after the first pass (Note how clean the re-steel is in the foreground on the left). A second pass with the hydro-blaster was necessary to remove the island of unsound concrete left over the rebar in the center of the photo.

Bid prices for Hydrodemolition

On maintenance contracts the bid prices have stayed consistently low $ 1.25/sf. to $3.23/sf. Only one construction project has been let and the price was $ 3.50/sf, this is almost an order of ten times less than mechanical removal, which bid for $ 28.79/sf for partial depth and $ 32.99/sf. for full depth removal. The limiting factor in getting hydrodemolition bid in Missouri has been the lack of contractors and hydro machinery and the need for numerous mobilizations of the equipment on most projects. It should be noted that allowing larger areas of deck to be opened up for hydrodemolition may cause additional traffic control costs. A summary of the costs of hydrodemolition for the study projects is listed in Table2 below.

Table 2: Bid prices for Hydrodemolition

Location	Date	Total Area	Bid Price	Total Cost
Bridge L-868, St. Marys/I-44, Franklin Co.	Fall 1996	5,800 sf.	$ 2.06/sf.*	$12,000
Bridge L-896, Rt.100/I-44, Franklin Co	Summer 1997	5,800 sf.	$ 1.25/sf.*	$7,250
Patching of several bridges on I-70, St. Louis	Summer 1997		$ 12/sy to $ 75/sy ** ($ 1.33/sf to $ 8.33 /sf)	
Bridge A01741 E&W, I-44, Greene County	1998	14,220sf. (1580sy.)	$ 3.50/sf ($ 31.50/sy.)	$49,770
1st construction contract specifying use of hydrodemolition.				
Bridge A-185R Ramp I-70, St. Louis City	1999		$ 3.23/sf. ($ 29.09/sy.)	

* One pass over whole bridge , vacuumed up and dumped on site. Maintenance hauled away rubble.
** Prices ranged from $ 12/sy to $ 75/sy depending on the amount of area contracted

TESTING PROCEDURES

Hydrodemolition does not cause damage to the good concrete left in place. Milling and jack hammering leave micro-fractures in the surface of the concrete, which can cause poor bond to patching or overlay material. Note: during surface preparation the milling step cannot be excluded if specifying hydrodemolition because the hydroblasting requires a rough concrete surface to initiate the removal process. Milling is a separate bid item and no savings with regard to milling are realized by using hydrodemolition over jack hammering. However, all micro-fracturing caused from milling is later removed by hydrodemolition leaving a more sound substrate.

Direct tension or pull off strength testing was done on each project using the ACI-503R, Field Test for Surface Soundness and Adhesion, method. Testing was performed on the original concrete after milling and either hydrodemolition or jackhammer removal. Additionally, direct tension tests were taken through the overlay and patch material into the original deck after the new concrete reached required strength.

The limited testing performed on these bridges showed hydrodemolition resulting in average pull

off strengths of the bond between the overlay and the hydrodemolition prepared deck to be 151 psi and 166 psi on maintenance work on bridges L-868 and A-135 Ramp respectively. (These pull off tests were taken after milling, hydrodemolition and the deck overlay was placed - see Notes: on Table 3 and Table 5) On the one construction contract using hydrodemolition, the average pull off strength was 121 psi. on Br. A-174. (see Notes: on Table 4) This compares to 80 psi pull off strength on Br. A-241 using jackhammer removal for patching and 140 psi pull off strength on a milled only area. (no jackhammer or hydrodemolition done in this area - see Notes: on Table 6) It was expected to get higher pull off strengths using hydrodemolition as the literature said strengths were up to twice as strong as surfaces using mechanical methods. It is believed that with a larger number of tests and with a more agile testing machine better results wouldl be obtained. The base plate of the tester used is very large (1 ft. x 1 ft) and testing on rough surfaces and around rebar made it hard to always ensure it was normal to the surface. Sweden has obtained pull off strengths up to 300 psi on testing of over 300 hydro blasted decks. (*Improving Concrete Bond in Repaired Decks.* Concrete International, September 1990)

Values for MoDOT testing are included in the tables below.

Table 3: Pull-Off Strength - Hydrodemolition

Bridge L-868, St. Mary's Way/I-44, Franklin Co. Tested: 10/2/97

Core No.	Tension, #	Pull Off, psi	Location of Failure
1	745	237	1/4" into overlay
2	**805**	**256**	**Interface, 50% old deck, 50% in overlay**
3	1080	344	1/4" into overlay
4	**230**	**73**	**Interface, only small part of overlay attached**
5	500	159	Middle of overlay, 1 3/4' down into overlay
6	**390**	**124**	**Interface about 75% old concrete**
Avg. Pull Off Strength = 199 psi			

Note: ACI calls for a minimum PO strength of 100psi. Only cores that break off at the interface give a true bond strength; Average of cores 2, 4 & 6 = **151 ps**i.

Bridge A-174, I-44 EBL, Greene Co **Tested**: 07/16/1999
(Constructon hydrodemolitrion contract with 1.75 in. latex modified concrete overlay.

Location No.	Core No.	Tension, #	Pull Off, psi	Location of Failure
1	1	180	57	100% in base
1	2	1020	325	100% in base
1	**3**	**420**	**134**	**100% interface**
Avg. Pull Off Strength = 172 psi				
2	**1**	**340**	**108**	**100% interface**
2	2	520	166	Not recorded
2	3	120	38	50% old patch/50% interface
Avg. Pull Off Strength = 104 psi				
3	1	320	102	100% in base
3	2	420	134	100% in base
3	3	960	306	100% in base
Avg. Pull Off Strength = 180 psi				

Note: ACI calls for a minimum PO strength of 100psi. Only cores that break off at the interface give a true bond strength; location 1, core 3 and location 2 core 1: average **121 ps**i.

Table 5: Pull-Off Strength – Hydrodemolition
Pull-Off Strength

Bridge A-135RP, I-70 WBL, ST. Louis Co **Tested: 3/01/00**

Location No.	Core No.	Tension, #	Pull Off, psi	Location of Failure
1	1	760	242	100% in epoxy
1	2	640	**204**	**Interface, 50% in base**
1	3	400	**127**	**100% interface**
1	4	980	312	100% in epoxy
Avg. Pull Off Strength = 191 psi				

Note: Only cores that break off at the interface give a true bond strength; location 1, core 2 and location 1, core 3 average **166 ps**i

Table 6: Pull-Off Strength – Mechanical Methods

Stage 3 - Silica Fume Overlay poured March 22, 2000,
Control: Mechanical equipment used for concrete removal

Location: Bridge A-241, I-270 wbl, St. Louis Co. **Tested: 05/24/2000**

Location No.	Core No.	Tension, #	Pull Off, psi	Avg. Pull Off, psi	Location of Failure
(Silicafume overlay on top of patch)					
1 (sf/patch)	**3**	120	38		broke in orig. concrete-1 7/8" thick, sf patch 2 1/4" thick
1 (sf/patch)	4	380	121	80	broke at epoxy, 2" sf & 2 1/4" limestone patch
1 (sf/patch)	1	100	**32**		**broke @ interface of overlay & orig. deck, no patch-2" thick sf**
1 (sf/patch)	2	400	**127**		**broke at interface-2"sf,no patch**
(Silicafume overlay on top of milled surface only)					
2 (sound sf)	5	360	**115**		**broke @ interface w/deck, very smooth-2 1/16" sf overlay**
2 (sound sf)	6	400	**127**	**140**	**broke @ interface w/deck, Interface rough 2 1/2" thick sf**
2 (sound sf)	7	560	**178**		**broke 100% @ interface w/orig. deck, interface smooth surface-**

sf = silica fume overlay

Note: Only cores that break off at the interface give a true bond strength;
For the cores over patches, core1and core 2 average **80 ps**i,

Conclusions

The follow findings were made from monitoring of various maintenance and construction contracts using hydrodemolition:

1. Cost can range from $ 12/sy ($ 1.33/sf) to $ 75/sy ($ 8.33/sf) depending on the amount of area contracted.
2. Hydrodemolition does not cause damage to the good concrete left in place. Milling and jack hammering leave micro-fractures in the surface of the concrete, which can cause poor bond to patching or overlay material.
3. In direct tension or pull off testing, limited field data has shown pulloff strengths between overlays or patches and surfaces prepared by hydrodemolition of (121-161 psi) slightly higher than a jack hammered surface (80 psi) or a milled only surface (140 psi).
4. Pulloff strengths for hydrodemolition prepared surfaces averaged 150 psi, which was not as high as expected. It is believed a bigger sample is needed and that with more testing the average would rise. Also there were problems keeping the pulloff tester at a perfect right angle to surface, which would cause lower readings. Sweden claims of pull off strengths for hydrodemolition prepared decks at least twice as strong as those od decks prepared using conventional methods. Sweeden has used hydrodemolition on over 300 bridges.[1]
5. Hydrodemolition leaves the rebar and deck ready in one operation.

Recommendations

1.) Results of this study show that hydrodemolition should be used on all construction projects where the cost of mobilization isn't prohibitive. Costs can become prohibitive because of many small spread out work zones caused by zoned repairs on structures with concrete superstructures integral with the deck. Costs also go up because of staged construction and difficult traffic control plans, or because hydrodemolition equipment isn't available in the area. However, the advantages gained from not damaging the remaining concrete as well as the speed of preparation of the existing reinforced concrete will far outweigh any additional costs and can save MoDOT and the contractors money. It is estimated that at least one-quarter of the bridge decks contracted by MoDOT for rehabilitation each year meet the criteria that could use hydro demolition and even be more economical than conventional jackhammer methods. It is believed that equipment and the number of contractors available to do hydrodemolition should increase and the bid prices go down as this new technology establishes itself.

2.) Maintenance bridge repair crews statewide should try to employ hydrodemolition whenever possible on bridge decks with good service ratings that are expected to remain in use for a long time. A video recording of the process was made on the first bridge using hydrodemolition in the St. Louis district and has been distributed to all district maintenance units to let them familiarize themselves with the process.

Principal Investigator and Project Members

John Wenzlick was the principal investigator for RDT with help in reporting by Anika Careaga and field testing by Steven Clark. Hydrodemolition work in the St. Louis area was initiated and coordinated by Pat Martens, District Bridge Inspection Engineer. Testing done on I-44, Greene County project was coordinated through Jim Blackburn, Resident Engineer in Buffalo, Mo. Testing done on the I-270, St. Louis County was coordinated through Lucy Smith, Senior Construction Inspector.

Affected Business Units and Principal Contact

All district maintenance and design personnel as well as Bridge Design should consider the use of new hydrodemolition techniques for repair of bridge decks. John 'JD' Wenzlick in Research, Development and Technology or Pat Martens of District 6 Maintenance can be contacted for further information.

Technology Transfer

Designers should use this report to promote the use of hydrodemolition in areas where it can be expected that the bid price will be close to that of conventional mechanical repair methods. Contractors should be more receptive when they find how much quicker it is and also the little or no preparatory work needed before pouring new concrete. Reduced time and preparation costs should outweigh the higher capital equipment costs as more subcontractors get into the hydrodemolition business.

Districts wanting to do hydrodemolition with their own maintenance forces already have an excellent videotape describing the process that was distributed statewide back in 1997. The video covers all steps in the hydrodemolition process, just as they were done on the St. Marys/I-44 bridge in Franklin County.

Bibliography

1. Silfwerbrand, Johan *Improving Concrete Bond in Repaired Decks.* Concrete International, September 1990

2. American Concrete Institute, P.O. Box 9094, Farmington Hills, MI 48333, *ACI Manual of Concrete Practice, 1997*

Appendix A
Work Plan

STUDY PROPOSAL

Date: July 18,1997

Project Number: RI97-025

Title: Hydrodemolition and Repair of various bridges, including monolithic repair and overlay with dense concrete and using Eccocrete admixture on Bridges L-996 and L-868, Franklin County.

Research Agency: Maintenance, Materials-District 6, RDT

Investigators: Pat Martens-Brdige Maintenance Engineer, Gary Branson-Senior Materials Inspector, J.D. Wenzlick-Senior R&D Engineer.

Background and Significance of Work: District 6 Maintenance has been looking for a more cost efficient and effective way to patch problem bridge decks and also to prolong the life and more permanently repair bridges not in the construction program. RD&T has also been wanting to test bond strength of overlays on surfaces prepared by milling versus waterblasting because of debonding problems showing up on latex modified and low slump bridge deck overlays.

Action Plan: Cost comparisons of hydrodemolition and patching or monolithically pouring a concrete overlay versus normal patching operations. Normal patching costs on other bridges versus cost of hydrodemolition on Br. A-135 and L-686R will be documented. Cost of hydrodemolition and monolithic pouring of concrete with Eccocrete admixture on Br. L-868 and of low slump concrete on Br. L-996 and estimate of savings over continued piece meal repair.

Literature Search: Will use maintenance records and construction bid process vs. those actually bid for this job for price comparisons. Will search ACI, TRB, NCHRP, TRIS and magazines for research on bond strength vs. surface preparation and monolithic patching and overlay pours.

Method of Implementation: Make this information available to the other Districts so that they can try hydrodemolition and any other useful information from this study in their bridge maintenance program. A video of the hydrodemolition will be made and distributed to all districts and others. If bond strength is shown to improve dramatically it will be proposed to the TRC that a construction project be let using hydrodemolition to prepare a deck for a dense concrete overlay and pending the success of this project changes in the general specifications will be proposed requiring hydrodemolition instead of milling.

Anticipated Benefits: Savings in patching of bridge decks in maintenance operations and longer lives between repairs of the same bridge. A possible solution to problems of bridge deck overlay debonding and a more efficient and less harmful method of repairing a reinforced concrete bridge deck.

Research Period: October, 1996 thru December, 1997

Funding: District 6 Maintenance funds will be used for all repair. RDT will fund the small amount of research time and testing needed.

WORK PLAN

Procedure: RDT staff will observe hydrodemolition, repair of decks and overlaying of decks. They will also take needed test specimens and do testing, chloride permeability and pull-off tests. They will do literature search and compile cost data and write a final report with District 6 input.

General Services will videotape and produce an informational video with District 6 input. District 6 will contract hydrodemolition work and materials and finishers to pour bridge overlays and special bridge crews will do patching and all labor involved in completing the repairs.

October, 1996

- Br. L-868, Franklin Co., Hydrodemolition and overlay with concrete with Eccocrete admixture.

June, 1997

- Br A-135, 7th Street & Cass Ave./ I-70, St. Louis City, Hydrodemolition and repair of bridge deck, asphalt overlay
- Br. L-686R, Hanley Rd./I-70, St. Louis Co., Hydrodemolition and repair of bridge deck, asphalt overlay.
- Br. L-896, Franklin Co. Hydrodemolition and repair of bridge deck and monolithic pour of low slump concrete overlay.

Staffing: J.D. Wenzlick, 2-Field Technicians

Equipment: In-house - Core drilling truck, pull off tester. Will run bond test of concrete overlay using ACI criteria, test chloride permeability in lab according to AASHTO T-242.

Budget: Observation in field
Chloride permeability testing
Pull-off Testing
Writing Final Report

Appendix B

Hydrodemolition Specification for Job J8I0647, I-44, Greene County bridges A01741 EBL and A01741 WBL.

(This is also the current **"Job Special Provision – Bridges"** for **Bridge Deck Surface Preparation Using Hydrodemolition**)

A. BRIDGE DECK SURFACE PREPARATION USING HYDRODEMOLITION (Bridge A01741 EBL and A01741 WBL)

General

The contractor shall use conventional scarifying to remove the initial 1/4 inch of the existing bridge deck surface.

Hydrodemolition shall then be performed over the entire top surface of the reinforced concrete bridge deck to provide a highly rough and bondable surface and to remove an additional 1/4 inch to 1/2 inch of sound and all unsound concrete during the initial hydrodemolition pass.

The contractor shall clean the surface with a vacuum system capable of collecting loose and wet debris and water in the same pass leaving a clean surface for immediate patching.

Unless otherwise stated, specification section references are from the version, in effect at the time of this contract, of the Missouri Standard Specifications for Highway Construction and its supplements.

Equipment

The hydrodemolition equipment shall be a computerized, self-propelled robotic machine that utilizes a high pressure water jet stream capable of attaining pressures in the range of 15,000 to 20,000 PSI and removing sound concrete to the depth specified. The equipment shall be capable of removing all unsound concrete during the initial pass and shall provide a highly rough and bondable surface. The equipment shall only be operated by individuals who have passed rigorous training as required by the equipment manufacturer.

Hand held high pressure wands or 35 lb maximum jackhammers operated at no more than a 45 degree angle from horizontal shall be used in areas that are inaccessible to the hydrodemolition equipment or in preparing deck repair areas or areas that require minor trim work to remove remaining unsound concrete.

Limitations on Equipment

The contractor shall not place more than 20 tons of equipment on a span during and after hydrodemolition until the concrete for the deck repairs has reached a compressive strength of 3200 pounds per square inch. The engineer may waive the 20 ton limit for the vacuuming operation if there are no areas where full depth removal exceeds 1/3 of the deck width and if there are no locations where there is more than 18 inches in length of full depth removal along the top of a girder.

The contractor shall take steps to prevent damage to existing reinforcing steel and shall not place wheels from heavy equipment, such as vacuum trucks, on deck areas where top layer of slab reinforcement has been left unsupported by the hydrodemolition process. Equipment shall be operated at speeds and in a manner that will not cause damage to the slab and girders.

Vehicles other than approved construction equipment shall not be permitted on those sections of the deck where hydrodemolition has begun. Contamination of the deck by construction equipment or from any other source shall be prevented.

Deck Preparation

1. Scarification

The contractor shall mechanically scarify the existing deck surface 1/4 inch in accordance with Missouri Std. Specifications. The scarifying equipment shall remove concrete within one inch of the curb lines and the scarifying debris shall be cleaned up with equipment that is equipped with fugitive dust control devices.

Measurement will be made longitudinally from end to end of bridge deck and transversely between roadway faces of new curbs. Payment for scarification and clean up shall be considered as completely covered by the contract unit

price per Sq. Yd. for Scarification of Bridge Deck.

2. Hydro (Total Surface)

The deck shall receive a Total Surface Deck Hydrodemolition after scarification. This shall consist of a continuous pass operation to remove an additional 1/4 inch to 1/2 inch of sound concrete, along with all deteriorated concrete in the deck.

All construction debris and/or scarifying debris and dust shall be completely removed from the bridge deck prior to the commencement of hydrodemolition.

The hydrodemolition equipment shall be calibrated on an area of sound concrete (seven feet by seven feet) as designated by the engineer to demonstrate the desired surface removal and roughness.

The hydrodemolition equipment shall then be moved to a second area (seven feet by seven feet) that is unsound, as designated by the engineer, to demonstrate the ability to remove all unsound concrete during the initial pass and providing a rough and bondable surface.

A non-working technical field representative shall be present on the project site during the calibration and the hydrodemolition surface preparation operation.

If the equipment does not demonstrate the ability to produce the desired results, as deemed by the engineer, the equipment shall be removed from the project site and other equipment shall be provided by the contractor for calibration and demonstration. No additional contract time or compensation will be allowed for re-mobilization and the re-calibration process if required.

The hydrodemolition surface preparation may begin after the engineer has approved the second calibration and the following five settings. The calibration and production settings shall be maintained and given to the engineer prior to and during hydrodemolition surface preparation by the contractor.

1. Water pressure gauge
2. Minimum water usage @ 55 gallons per minute
3. Machine staging control (step)
4. Nozzle size
5. Nozzle speed (travel)

Any of the above settings may be changed as directed by the Engineer to maintain the desired result. When the designated level of removal is attained, the settings shall be recorded and maintained throughout the hydrodemolition operation.

The calibration procedure specified shall be required on each structure, each time hydrodemolition is performed. The depth of removal shall be checked and readings documented every 30 feet along the cutting path, and if necessary, the equipment re-calibrated to insure the minimum removal of sound concrete to achieve required roughness for bond.

In areas of concrete girders and diaphragms, concrete shall not be removed below the bottom of the slab.

Cleaning of the hydrodemolition debris shall be performed with a vacuum system equipped with fugitive dust control devices and capable of removing wet debris and water all in the same pass. The deck shall then be blown dry with air to remove excess water. Cleaning shall be done in a timely manner, before debris and water is allowed to dry on the deck surface. This operation shall leave a clean surface suitable for immediate patching.

Any unsound concrete or original deck surface found unsatisfactory after the initial hydrodemolition surface preparation pass shall be removed or corrected by the contractor at no additional expense to the state, except at noted in Deck Repair (Formed).

Unsound concrete is defined as existing bridge deck concrete that is deteriorated, spalled, or determined by the engineer to be unsound. Sounding will be done after the deck is dried as specified above and frost free.

Particular care shall be taken not to disturb or damage reinforcing bars. If, when removing deteriorated concrete by hydrodemolition or cleaning equipment, the bond between the existing concrete and a reinforcing bar has been destroyed , the concrete adjacent to the reinforcing bar shall be removed to a depth that will permit the concrete to bond to the entire periphery of the bar so exposed. A minimum of 3/4 inch clearance shall be provided at no additional cost to the state.

Bars damaged or broken by hydrodemolition or the cleaning operations shall be replaced by the contractor at no additional cost to the State. The State may replace and pay for any bar that has lost more than 10 percent of its cross sectional area due to deterioration. Replacement shall be made by splicing 24 diameters each side of the damage with new bars of the same size. The contractor is required to provide a minimum of 3/4 inch clearance around the replaced bar.

Surface preparation by hydrodemolition, shielding, runoff control and containment, vacuuming, disposal of material, additional removal of deteriorated concrete by hand methods and all other aspects of work necessary to prepare the deck for the placement of the overlay, except as specified in Deck Repairs (Formed), shall be included in Hydro (Total Surface) (Sq. Yd.). Measurement for Hydro (Total Surface) will be made longitudinally from end to end of bridge deck and transversely between roadway face of new curbs.

3. Deck Repairs

Areas where removal of unsound concrete does not expose the bottom mat of reinforcing in the deck shall be patched with latex modified concrete and placed monolithically with the concrete wearing surface. Hand vibrators shall be used for placement of latex concrete that extends below the top layer of reinforcement.

No separate measurement or payment will be made for repairing areas that do not extend the full depth of the slab. Payment shall be considered as completely covered by the contract unit prices for Latex Modified Concrete Placement (Sq. Yd.) and Latex Modified Concrete, additional (Cu. Yd.).

The entire thickness of the slab shall be removed in locations where removal of unsound concrete exposes the bottom mat of slab reinforcing. Payment for concrete removal and repairs in these areas will be made under Deck Repairs (Formed).

3a. Deck Repairs (Formed)

Areas where the entire thickness of the slab has been removed shall be repaired by the contractor prior to placement of the overlay. A rectangular boundary perimeter will be determined and marked by the engineer after hydrodemolition.

The contractor shall establish vertical sides along the perimeter by saw cutting or chipping vertically the first 1/2 inch of the deck repair area. A minimum 1 inch vertical face shall be provided at the top of the repair as shown on the plans. The vertical sides at the bottom shall extend from the bottom of the slab up to at least 1/2 inch above the bottom mat of reinforcing.

Reinforcing bars and concrete surfaces exposed by the use of chipping hammers and hand tools shall be required to be cleaned by sandblasting or hand held hydrodemolition equipment.

Concrete for repairing full depth removals shall be Class B-2 as described in Sec 501. Hand vibrators shall be used for all deck repairs below the top layer of rebar. The surface of the repair shall be given a very rough texture while still plastic by use of a wire comb or other approved texturing device which will produce a bondable surface acceptable to the engineer. The textured surface shall not be subjected to traffic.

The overlay shall not be applied on areas of deck repair until the concrete has cured at least 72 hours. Traffic will not be permitted on the bridge until the concrete has reached a compressive strength of 3200 pounds per square inch.

The formed repair area shall not be subject to a direct wheel load from construction traffic until the concrete has reached 3200 psi. Type III cement, in accordance with Sec 1019, may be used to accelerate the set. The course aggregate shall be Gradation E, Sec. 1005.1.3.

Quantities for Deck Repair are estimates only. Payment for the complete repair in place including labor, materials, cleaning, and forming will be covered under Deck Repair (Formed). The quantity for payment will be based on the actual area of the boundary perimeter as measured in the field by the engineer to the nearest Sq. Ft.

Special Conditions

Traffic shall be handled on the adjacent structure during construction (See roadway plans). Hydrodemolition shall not impede or interfere with traffic being maintained in the vicinity of the work.

The contractor shall provide shielding, as necessary, to insure containment of all dislodged concrete within the removal area in order to protect the traveling public from flying debris both on and under the work site.

Potable water, as defined in Sec 1070, shall be used and shall be provided by the contractor. If planning to access hydrants, it is the contractors responsibility to contact and make the appropriate arrangements with the proper water district.

The contractor shall take necessary precautions during Hydrodemolition to prevent damage to the remaining structure and adjacent property as a result of runoff. All deck drains shall be temporarily blocked and pea gravel aggregate dams installed every 150 feet to slow the water down and strain the run-off.

The contractor shall control dust and run-off in accordance with applicable governmental agencies.

The contractor is responsible for the disposal of all material removed, including but not limited to, material collected by vacuuming the deck.

B. LATEX MODIFIED CONCRETE OVERLAY

The intent is to apply a 1 3/4 inch minimum overlay to an elevation of 1 1/4 inch above the existing deck surface. The overlay thickness will vary and will be determined by the amount of sound and unsound concrete removed by hydrodemolition.

The overlay shall not be applied on areas of Deck Repair (Formed) until the repair concrete has cured at least 72 hours.

The surface shall be prepared and overlay placed in accordance with Sec 505.20. If the wetted surface is allowed to dry prior to placement of the overlay it shall be re-cleaned and wetted.

Where surface preparation has left alternate deep and shallow areas that do not require deck repair the deep sections may be partially filled in advance with latex modified concrete so that the material stiffens enough that it will not roll back under the paving screeds. In lieu of filling the deep areas in advance of paving, the entire depth may be placed at one time, if care is taken to insure that the latex concrete is thoroughly worked into these areas and provided that the concrete does not roll back under the paving screeds. Hand vibrators shall be used in areas where concrete is being placed around reinforcement.

Some of the latex modified concrete mixture shall be brushed on immediately ahead of the overlay in accordance with 505.20.8.3. Aggregate remaining after the grout paste has been used up shall be removed from the deck and disposed of.

All material, equipment, labor and any other incidental work necessary for placing the overlay in accordance with the 505.20 shall be considered completely covered by the following two items:

1. Latex Modified Concrete Overlay (Sq. Yd.) - Payment for this item covers Latex Modified Concrete, labor,

materials, and equipment required to place the latex concrete overlay at 1 3/4 inch depth. The quantity is measured longitudinally from end to end of bridge deck and transversely between roadway face of new curbs.

2. Latex Modified Concrete, Additional (Cu. Yd.) - Includes material cost only, for furnishing Latex Modified Concrete to the job site in place. The intent of this item is to pay for additional material used for the variable depth overlay thickness in excess of 1 3/4 inch. Labor and equipment costs shall be considered incidental to, and covered by, Latex Modified Concrete Overlay.

The state has indicated a predetermined contract unit price in the proposal of $350.00 per cu. yd. for Latex Modified Concrete, Additional. The quantity listed in the proposal for this item is approximate. The actual pay quantity will be determined after concrete is in place.

Appendix C

“General Special Provisions – Bridges” for Repairing Concrete Deck

The following two types of deck repair are covered in this special provision:

Half-Soling - Partial concrete removal and replacement.

Full Depth Repair - Full depth concrete removal and replacement.

The anticipated type/types of deck repair shall be as specified on the bridge plans. The type/types of repair and areas to be repaired will be outlined by the engineer.

1. Preparation of Existing Deck Surface

a. Decks to be Covered with Concrete Wearing Surface

The existing deck shall be scarified at least 1/4 inch deep as specified elsewhere in these special provisions.

Slight deck imperfections of no more than 1/2 inch in depth below the surface of the scarified deck, surrounded by sound concrete and not exposing the reinforcing steel shall not be half-soled. Before the application of the concrete wearing surface, these areas shall be cleaned by hand tools and sandblasting or by hydroblasting to remove all dirt, loose material, and deteriorated concrete. Concrete for these areas shall be placed monolithic with the concrete wearing surface.

No direct payment will be made for cleaning these areas.

b. Decks to be Covered with Asphaltic Concrete Wearing Surface

Slight deck imperfections of no more than 1/2 inch in depth and surrounded by sound concrete shall be cleaned to remove all dirt, loose material, and deteriorated concrete without exposing the reinforcing steel. No direct payment will be made for cleaning these areas.

c. Decks to be covered with Epoxy Polymer Concrete Overlay

Preparing and cleaning the existing bridge deck shall be in accordance with the requirments described in the special provisions for "Epoxy Polymer Concrete Overlay".

2. Repairing Concrete Surface (Half-Soling)

a. General

Deteriorated concrete exceeding the depth specified in "Preparation of Existing Deck Surface" shall be repaired by half-soling.

A boundary perimeter with vertical sides shall be established outside the deteriorated area by saw cutting, chipping or hydroblasting. The area of repair shall be made approximately rectangular with the sides being generally normal to grade.

The minimum depth of repair shall expose the upper layer of the top mat of reinforcing bars.

If, when removing the deteriorated concrete by conventional hand/mechanical equipment, the bond between the existing concrete and a reinforcing bar has been destroyed or more than half the diameter of a reinforcing bar in the top mat is exposed, the concrete adjacent to the reinforcing bar shall be removed to a depth that will permit the concrete to bond to the entire periphery of the bar so exposed. A minimum of 3/4 inch

clearance shall be required.

If, when removing the deteriorated concrete by hydro demolishing equipment, the bond between the existing concrete and a reinforcing bar has been destroyed, the concrete adjacent to the reinforcing bar shall be removed to a depth that will permit the concrete to bond to the entire periphery of the bar so exposed. A minimum of 3/4 inch clearance shall be required.

The deteriorated concrete shall be removed as required to provide a good sound concrete on which new concrete can be placed and satisfactorily bonded. Particular care shall be taken not to disturb or damage reinforcing bars.

Any half-soling required in the areas designated "Special Repair Zones" shall be completed in alphabetical sequence as shown on the bridge plans. Before placing concrete in areas adjacent to areas of subsequent repair, the concrete shall be separated with a material such as polyethylene sheets to aid in removal of old concrete. Removal and repair shall be completed in one zone of special repair and concrete shall have attained a compressive strength of 3200 pounds per square inch before work can be started in the next zone of special repair. The remainder of the bridge deck adjacent to Special Repair Zone "A" shall be repaired as shown on the bridge plans.

b. Concrete Superstructure (Hollow Slab and Solid Slab)

If any single repair area does not exceed 4 square feet in size and the total repair within a "Special Repair Zone" does not exceed 12 square feet, then "Special Repair Zone" repair does not apply for that zone.

When a void in the deck area of a hollow slab bridge is exposed during repair it shall be patched as approved by the engineer in a manner that will maintain the void area completely free of concrete. Half-sole repair shall include all material
and work required to maintain the original voids.

c. Concrete Superstructure (Box Girder)

If any single repair area does not exceed 9 square feet in size and the total repair within a "Special Repair Zone" does not exceed 27 square feet, then "Special Repair Zone" repair does not apply for that zone.

Half-sole repair in the Special Repair Zones, on either side of the bents, shall be to a depth that will not expose half the diameter of the large longitudinal reinforcing. When removal of deteriorated concrete exposes half or more than half the diameter of the longitudinal reinforcing, full depth removal shall be made.

Heavy construction traffic will not be permitted over the girder that is undergoing repair.

3. Full Depth Repair

a. General

A boundary perimeter with vertical sides shall be established outside the deteriorated area by saw cutting, chipping or hydroblasting. The areas of repair shall be made approximately rectangular with the sides being generally normal to grade. These areas shall be carefully removed taking care not to disturb or damage the reinforcing. Except for box girder type bridges a saw cut outside the deteriorated area shall also be made on the bottom of the deck or removal shall be made in an acceptable manner.

b. Concrete Superstructure (Hollow Slab and Solid Slab)

The sequence of repair in the "Special Repair Zones" shall be as

outlined under half-soling and completed in alphabetical sequence as shown on the plans.

When a void in the deck area of a hollow slab bridge is exposed during repair it shall be patched as approved by the engineer in a manner that will maintain the void area completely free of concrete. Full depth repair shall include all material and work required to maintain the original voids.

c. Concrete Superstructure (Box Girder and Deck Girder)

Total width of full depth removal shall not exceed 1/3 of each deck width at one time.

For any area of deck repair that extends over a concrete girder and is more than 18 inches in length along the girder, the concrete removal shall stop at centerline of girder and repair completed in this area. Prior to continuing work in this area the concrete shall have attained a compressive strength of 3200 pounds per square inch. Heavy construction traffic will not be permitted over the girder that is undergoing repair. Where full depth repair extends over a diaphragm or girder and the deteriorated concrete extends into the diaphragm or girder all deteriorated concrete shall be removed and replaced as full depth repair. Concrete in girders shall not be removed below the intersection of the deck haunch of the girder without prior review and approval by the engineer.

The sequence of repair in the "Special Repair Zones" shall be as outlined under half-soling and completed in alphabetical sequence as shown on the plans.

Interior falsework installed by the contractor resting on the bottom slab of box girder type bridges shall be removed, except for structures where access holes are not available.

4. Construction Requirments

a. General

All loose, deteriorated and unsound concrete in the designated repair areas shall be removed by conventional hand/mechanical equipment, hydro demolishing equipment or other approved equipment to a depth as specified herein and as directed by the engineer.

The conventional hand/mechanical equipment consists of the following: Pavement breakers of the 35 pound class may be used for concrete removal and chipping hammers of the 15 pound class shall be used to remove concrete from beneath any reinforcing bars where required, unless in the opinion of the engineer, another method would be less damaging to the concrete and reinforcement to remain in place. The bits shall be sharp in order to reduce pounding.

As an option to the conventional hand/mechanical equipment listed above, the contractor will be allowed to use hydro demolishing equipment in repairing the concrete deck.

The hydro demolishing equipment shall be capable of developing a high-pressure water jet of 16,000 psi. The water jet shall be capable of being directed so as not to leave any areas unexposed to the high-pressure water pattern. The equipment shall be capable of removing concrete to the depth specified herein and/or on the plans, and be capable of removing rust and concrete particles from exposed reinforcing bars.

All water used in hydro demolition shall be potable as defined by Sec. 1070. Stream or lake water will not be permitted.

The contractor shall take necessary precautions during hydro demolition to prevent damage to the remaining structure and adjacent property as a result of runoff. Hydro demolition shall not impede or interfere with traffic being maintained in the vicinity of the work.

Particular care shall be taken not to disturb or damage reinforcing bars. All exposed reinforcing bars shall be thoroughly cleaned by sandblasting or hydroblasting. Cut or broken bars or bars having 10 percent or more cross section area lost shall be spliced 24 diameters each side of the damage with new bars of the same size.

If an area of deck repair is large enough to affect the structural

integrity of the deck, it shall be referred to the engineer to determine a sequence of further deck repair.

All material removed shall be disposed of as approved by the engineer.

After removal of deteriorated concrete, the area to be repaired shall be sandblasted or hydroblasted to remove all foreign matter, and shall be cleaned to remove all dirt, free standing water and loose material. If the hydro demolishing process is used, sandblasting or additional hydroblasting will not be required unless the bonding surface of the repair area is unsatisfactory or becomes contaminated prior to placement of repair concrete as determined by the engineer. After the area has been cleaned, an epoxy bonding compound or cement grout shall be applied to the old concrete to remain in place and to be in contact with the new concrete.

An epoxy bonding compound shall be used in accordance with Sec 623 for all structures with the following exceptions:

A cement grout shall be used on structures with continuous concrete superstructures (box girder, hollow slab, and solid slab) and on structures where a cathodic protection system is to be installed. The area to receive the grout shall be cleaned as stated above, saturated with water and painted with a neat cement grout of painting consistency in accordance with Sec 703.3.21.

b. Decks to be Covered with Concrete Wearing Surface

Immediately following application and before the epoxy bonding compound or cement grout has begun to set, Deck Repair Concrete shall be placed in the area to be repaired up to 1/4 inch of the top surface of the original deck and finished by the

use of a wire comb or other approved texturing device which will produce a rough surface for bonding of the concrete wearing surface that is acceptable to the engineer.

All joints shall be formed to match any existing joint pattern.

c. Decks to be Covered with Asphaltic Concrete Wearing_Surface or Epoxy Polymer Concrete Overlay

Immediately following application and before the epoxy bonding compound or cement grout has begun to set, Deck Repair Concrete shall be placed in the area to be repaired up to the top surface of the original deck and finished with a light broom texture which will produce a surface for bonding of the deck seal that is acceptable to the engineer.

All joints shall be formed to match any existing joint pattern.

5. Deck Repair Concrete

a. Decks without a Cathodic Protection System to be Installed

Concrete for repairing concrete deck shall be Class B-2 (except on solid slab, voided slab and concrete box girder structures, in which case the deck repair shall be the same as the concrete in the existing deck) and shall not be opened to any traffic until the concrete has reached a compressive strength of 3200 pounds per square inch. Type III cement may be used to accelerate the set. The coarse aggregate shall be Gradation E, Sec. 1005.1.5.

Accelerating additives containing chlorides will not be approved.

1) Decks to be Covered with Concrete Wearing Surface

The repaired areas shall be cured with wet mats in accordance with Sec 703.3.17 for curing surfaces other than riding surfaces. Curing by transparent or white pigmented curing compounds will not be allowed.

2) Decks to be Covered with Asphaltic Concrete Wearing_Surface

The repaired areas shall be cured with wet mats in accordance with Sec. 703.3.17 for curing surfaces other than riding surfaces or by applying a coat of emulsified asphalt (SSl, SS-lH, CSS-l, or CSS-lH). If emulsified asphalt is used, the emulsified asphalt shall be removed to the degree required by the

surface preparation for the deck seal to be placed. Curing by transparent or white pigmented curing compounds will not be allowed.

b. Decks with a Cathodic Protection System to be Installed

Concrete for repairing concrete deck shall be Class B-1 and shall not be opened to any traffic until the concrete has reached a compressive strength of 3200 pounds per square inch. Type III cement may be used to accelerate the set. The coarse aggregate shall be Gradation E, Sec. 1005.1.5.

All half-sole repairs made on the deck shall be Class B-1 concrete that has a chloride ion content of 5 pounds per cubic yard, except at the location of the rebar probes which is specified in the "Alternate Cathodic Protection Systems" special provision.

All full depth repairs made on the deck shall be chloride-free Class B-1 concrete from the bottom of the deck to within 3/4" of the lowest rebar of the top layer of reinforcing steel. The remainder of the repair shall be Class B-1 concrete with a chloride ion content of 5 pounds per cubic yard, except at the location of the rebar probes which is specified in the "Alternate Cathodic Protection Systems" special provision.

Accelerating additives containing chlorides will not be approved.

The repaired areas shall be cured with wet mats in accordance with Sec 703.3.17 for curing surfaces other than riding surfaces. Curing by transparent or white pigmented curing compounds will not be allowed.

c. Decks to be covered with Epoxy Polymer Concrete Overlay

Material for repairing the existing concrete deck shall be Class B1 or B2 concrete.

Accelerating additives containing chlorides will not be approved.

If the material for deck repair is Class B1 or B2 concrete, it shall not be opened to traffic until the concrete has reached a compressive strength of 3200 pounds per square inch. Type III cement may be used to accelerate the set. The coarse aggregate shall be Gradation E, Sec 1005.1.5. The cleaning of the deck and application of the epoxy polymer concrete overlay may proceed after a twenty-eight day cure.

The repaired areas shall be cured with wet mats for 72 hours or until the required design strength is obtained. Curing by transparent or white pigmented curing compounds will not be allowed.

6. Method of Measurement

The extent of repair may vary from the estimated quantities, but the contract unit price shall prevail regardless of the variation.

Repairing concrete surface (Half-Soling) will be measured to the nearest square foot of area half-soled.

For decks to be covered with a Concrete Wearing Surface, repairing concrete surface (Full Depth Repair) will be measured to the nearest square foot of that part of the existing deck area replaced with new concrete from the bottom of the deck up to 1/4 inch of the top surface of the original deck.

For decks to be covered with an Asphaltic Concrete Wearing Surface or polymer concrete overlay, the repairing concrete surface (Full Depth Repair) will be measured to the nearest square foot of that part of the existing deck area replaced with new concrete for the total deck thickness.

Areas thus measured will be (Half-Soling) or (Full Depth Repair) with no measurement duplication allowed.

7. Basis of Payment

Payment for the above described work including all materials, equipment, labor and any other incidental work necessary to complete the item shall be considered as completely covered by the contract unit price for "Repairing Concrete Deck (Half-Soling)" per square foot or "Full Depth Repair" per square foot.

No direct payment will be made for concrete removal and replacement below the intersection of the deck haunch.