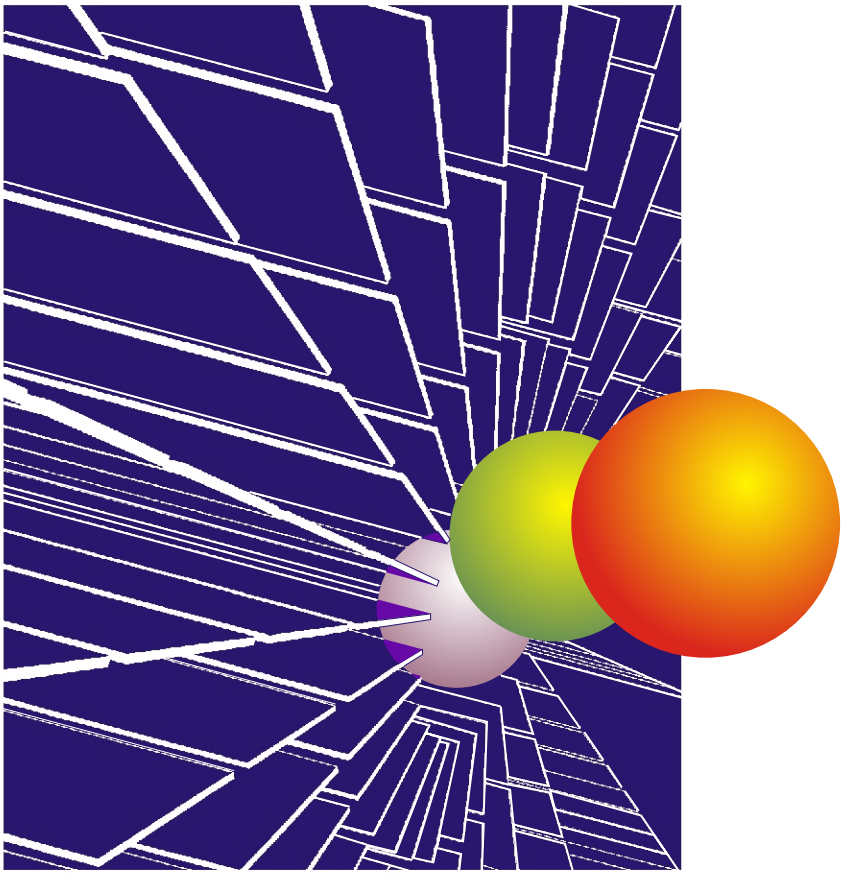
MoDOT

Research, Development and Technology

RDT 02-003

Effects of Heavyweight Jackhammer

RI 98-021



December, 2002

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. RDT02-003	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Effects of Heavyweight Jackhammer		5. Report Date December 16, 2002
		6. Performing Organization Code MoDOT
7. Author(s) Missouri Department of Transportation		8. Performing Organization Report No. RI98-021
9. Performing Organization Name and Address Missouri Department of Transportation Research, Development and Technology P. O. Box 270-Jefferson City, MO 65102		10. Work Unit No. 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Missouri Department of Transportation Research, Development and Technology P. O. Box 270-Jefferson City, MO 65102		13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code MoDOT
15. Supplementary Notes The investigation was conducted in cooperation with the U. S. Department of Transportation, Federal Highway Administration.		
16. Abstract The objective of this study is to determine the extent of damage, if any, of using a heavyweight jackhammer, 65 lbs., as opposed to a lighter weight jackhammer, 35 lbs., for removing deteriorated concrete during bridge deck repair. The use of a heavier weight jackhammer allows more efficient and timely repair operations. However, there are questions of potential damage to the bridge deck when using a heavyweight jackhammer. In conjunction with the above findings it was determined that allowing the use of 65 lb. jackhammers for contracted maintenance repair projects (on un-programmed bridges) is not in conflict with MoDOT's special provisions limiting operations to a maximum 35 lb. jackhammer on bridge rehabilitation construction contracts.		
17. Key Words Jackhammer, concrete repair, damage	18. Distribution Statement No restrictions. This document is available to the public through National Technical Information Center, Springfield, Virginia 22161	

19. Security Classification (of this report) Unclassified	20. Security Classification (of this page) Unclassified	21. No. of Pages 58	22. Price

Form DOT F 1700.7 (06/98)

Final Report

RI 98-021

Effects of Heavyweight Jackhammer

MISSOURI DEPARTMENT OF TRANSPORTATION
RESEARCH, DEVELOPMENT AND TECHNOLOGY

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JEFFERSON CITY, MISSOURI
DATE SUBMITTED: December 16, 2002

EXECUTIVE SUMMARY

The objective of this study was to determine the extent of damage, if any, of using a heavyweight jackhammer, 65 lbs., as opposed to a lighter weight jackhammer, 35 lbs., for removing deteriorated concrete during bridge deck repair. The use of a heavier weight jackhammer allows more efficient and timely repair operations. However, there are questions of potential damage to the bridge deck when using a heavyweight jackhammer. In conjunction with the above findings it needed to be determined whether allowing the use of 65 lb. jackhammers for contracted repair projects on un-programmed bridges is in conflict with MoDOT's special provisions limiting operations to a maximum 35 lb. jackhammer on bridge rehabilitation contracts.

Comparison with eight other states showed Missouri's current use of 65 lb. jackhammers for maintenance operations and 35 lb. jackhammers as a contractor requirement is in the mid range of the states requirements in both categories. American Concrete Institute suggests no more than 30lb. jackhammers but Iowa was the only state specifying a jackhammer this light. Cores were taken in patched areas prepared using either 35 lb. or 65 lb. jackhammers to compare the compressive and direct shear strengths of the concrete but showed no significant difference no matter which jackhammer was used. Additionally, several core samples were taken from the bottom of the excavated holes for visual examination. Only a few micro-cracks could be found in the samples. There was found also to be no correlation of more damage with the 65 lb. jackhammer than the 35 lb. one. An extensive number of direct shear tests, or pull-off tests, were taken in both categories of patches but no correlation between lower pull-off strengths using the heavier jackhammer could be proven.

After all of the testing done it could not be proven that the 65 lb. jackhammer was more destructive to the concrete left in place than the 35 lb. jackhammer. The deciding issue here is the condition of the bridge decks themselves. Whether the decks are good enough to rehabilitate or because of the advanced deteriorated state of the concrete they should simply be patched until the time they can be replaced. For those decks in good enough condition, they should be rehabilitated by construction contract and it is recommended to keep using the job special provisions for concrete repair that specifies a maximum 35 lb. jackhammer. It is, however, recommended that for maintenance contracts in the future to go back to the specifications used in 1998. That patching of older bridge decks, which are not considered in good enough condition to be rehabilitated (basically pot hole repair), should specify a maximum 65 lb. jackhammer in order to allow more efficient and timely repair operations both by MoDOT maintenance crews or by contractors in contracted maintenance repair projects.

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Introduction

In 1998 the Missouri Department of Transportation for the first time started letting maintenance contracts for bridge deck repairs. Only department maintenance crews had previously repaired these. A maximum 65 pound class breaking hammer was specified (see Appendix D). This is the same as that used by the local maintenance crews and discussed in section 10.18.3 of the MoDOT Maintenance Manual (see Appendix C). The 65 lb. jackhammer was specified because Maintenance found it quicker and more efficient for short-term pothole repairs. These bridges are different from the bridges normally being rehabilitated by construction contracts in MoDOT's Statewide Transportation Improvement Plan (STIP). This type of repair is specified by the Bridge Division Job Special Provision, JSP - *Repairing Concrete Deck*, (see Appendix B), and limits hand/mechanical pavement breakers to the 35 pound class for concrete removal.

In 1999 MoDOT changed the specifications for this pothole repair work to allow only 35 lb. jackhammers (see Appendix E). Since the same contractors bid on these new maintenance repair contracts as bid on rehabilitation construction contracts, MoDOT was concerned there may be confusion by contractors as to what procedures MoDOT really wanted followed. There was a fear that the contractor may try to use the heavyweight (65 lb.) jackhammer on a rehabilitation contract and cause possible damage to the original concrete which was left in place on the newly rehabilitated bridge. Usually bridge rehabilitation projects consist of repair to areas of deteriorated concrete on the bridge deck, and/or widening the bridge, and then placing a dense concrete overlay for a new riding surface. This type of repair is expected to have at least a 20 year service life.

Objectives

The Research, Development and Technology unit was given the task to see if for maintenance contracts it would be acceptable to go back to using 65 lb. jackhammers to allow quicker, more efficient removal of bad concrete. Conversely, if it could be proven the heavier jackhammers were not causing any damage, could they possibly be used on construction rehabilitation jobs?

Present Conditions

Up until 1998, district maintenance crews have done all the repair patching needed on bridge decks. The decks needing repair may have a NBIS deck rating of 4or 5. These bridges have immediate need of repair of potholes or have had continual need for repair in the past. If the district knows that these bridges are not programmed for rehabilitation in the near future they schedule them for repair. They sound the decks for deteriorated concrete and use the 65 lb. class jackhammers to excavate the deteriorated concrete. Usually a fast setting concrete patching material is used to repair these holes, the most commonly used across the state is "Duracrete" a gypsum based hydraulic cement mix, so that they do not have to leave a lane closed to traffic overnight. This patching material allows traffic on it quickly, has little shrinkage problems and is fairly durable, however, its longevity may be only several years due to weathering problems. This type of repair will not bring the NBIS rating up whereas a thorough rehabilitation construction contract will.

With the increased amount of work required on deteriorating bridges and fewer maintenance personnel to do it, the larger districts, Districts 4, 6 and 8 – Kansas City, St. Louis and Springfield respectively, nave been contracting out this repair patching since 1998. This type of patching is not considered rehabilitation and does not usually raise the NBIS ratings of the decks. These decks usually have an NBIS deck rating of less than "6", but still need repaired until they can be programmed for replacement. That is why this study is seeking to determine how heavy jackhammers should be allowed by the new maintenance repair specifications.

In contrast to this, decks scheduled for rehabilitation in the STIP are usually within a major roadway re-surfacing project and are needed to widen the decks to bring them up to new traffic needs or current design specifications. These bridges are expected to be brought up to like new condition and the NBIS deck rating will subsequently go back up to 8. These bridges are covered by the current construction Job Special Provision and have always limited the size of jackhammer for concrete removal to 35 lbs.

Technical Approach

Task 1. Compare MoDOT specifications and methods of concrete repair with other states. The comparison should look at both maintenance procedures as well as contracted construction projects.

Task 2. Observe procedures of removing deteriorated concrete on maintenance repairs, both by MoDOT crews and contractors, and also procedures used by contractors in rehabilitation contracts.

Task 3. Core the concrete from the bottom of an excavated repair for each of the three circumstances mentioned in task 2, to see if any micro-cracking or other damage was done by the jackhammers and was being left in place. Also to see if there was less micro-cracking caused by using the 35 lb. jackhammer than when the 65 lb. jackhammer was used.

Task 4. Conduct pull-off testing on all three circumstance of Task 2. First, test pull-off or tensile strength on the substrate (remaining original concrete deck after excavating the deteriorated concrete). Second, after the excavations are patched and the new concrete patch has cured, test pull-off strength through the patching concrete into the substrate to see whether the bond of the patching concrete has been affected, depending on whether the 35 lb. jackhammer or the 65 lb. jackhammer has been used.

Results and Discussion (Evaluation)

Task 1. A chart is presented below, in Table 1, summarizing the different jackhammer specifications of neighboring states along with North Carolina and Ohio who responded to an e-mail request. Some narrative comments from each state are attached in Appendix G.

Table 1

Jackhammer Specifications of Other States
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State	Contractor Requirements		Maintenance Crews	
ACI Manual of Concrete Practice	*Max Recommended*	30 pound	*Max Recommended*	30 pound
Missouri	*Pavement Breaker* *Chipping Hammer*	35 pound 15 pound	*All Conditions*	65 pound
Kansas	*Partial Depth Repairs* *Full Depth Patching* *Angle*	15 pound 30 pound (w/in 6 inches of edges) 15 pound (remaining 6 inches) So no damage	*Pavement Breaker* *Chipping Hammer*	30, 60, 90 pounds 15 pound
Arkansas	*All Conditions* *Angle*	45 pound 45 degrees from deck	*All Conditions* *Angle*	90 pound Any angle
Illinois	*Pavement Breaker* *Chipping Hammer* *Angle*	45 pound 15 pound 45 degrees	*Divisions Vary*	25 (chipping) 35, 40, 45, 60, 90 (substructure) pounds
Iowa	*Shallow Repair* *Full Depth Repair*	15 pound 30 pound 15 pound (at edge)	*Shallow Repair* *Full Depth Repair*	15 pound 30 pound 15 pound (at edge)
Tennessee	*Full Depth Repair* *Partial Depth Repair* *Chipping Hammer*	90 pound (except over beams) 60 pound (including over beams) 15 pound		
North Carolina	*All Conditions*	35 pound		
Ohio	*All Conditions* *Angle*	35 pound 45 degree		
Nebraska	*Pavement Breaker* *Chipping Hammer* *Angle*	60 pound 30 pound 45 degree		

A review of adjacent states DOT's specifications for deck repairs both by maintenance and construction contract were reviewed to see what standard practice was in the Midwest area. Specifications showed a wide variation of jackhammer classes used, from 15 – 90 lbs., both as contract requirements and by maintenance crews. Generally construction requirements limit jackhammers to 30 – 45 lb. and maintenance crews use 60-90 lb. jackhammers.

Task 2. Procedures of removing deteriorated concrete were observed first on maintenance repairs by MoDOT crews and second of maintenance repairs by contractors. Third, repair procedures used by contractors in rehabilitation contracts were observed. Specifications for excavating the deteriorated concrete are being substantially followed on both maintenance and construction projects. The operators tend to use the heaviest jackhammers they can before switching to a chipping jackhammer around the exposed rebar. Hitting the rebar with a heavy jackhammer does carry the stresses further into the good concrete.

In maintenance repair contracts the contractors would rather use the 65 lb. jackhammers because they can clean a hole more quickly than the 35 lb. ones and can get more production in a one-day (one-night) work period. (More commonly they are required to work at night.) The contractor's personnel on a maintenance repair job are also not in a closed lane behind a permanent barrier as most construction jobs are. They are behind barrels in a temporary work zone and need to get enough holes cleaned out so that patches can be filled with concrete and the lane reopened to traffic.

Task 3. Visual Examinations of Cores:

Hitting the rebar with a heavy jackhammer does carry the stresses further into the good concrete. However, visual examination of 20 cores where jack hammering or ringing of the rebar occurred using both 65 lb. and 35 lb. jackhammers were inspected and did not show any extensive micro-fracturing. The cores were first examined with the naked eye; some were treated with penetrating dye, and then examined under a microscope.

In-depth descriptions of fieldwork that took place on Bridge N-201, St. Louis County is described below:

February 2 & 17, 1999 - obtained cores from the westbound lane of Bridge N-201 being patched by the District 6 bridge repair crew. Took 2 cores in repair areas, 1core in an area using a 65 lb. jackhammer and 1 core in area using a 35 lb. jackhammer. These cores were observed under a microscope.

Core #1 - The surface, which had been at the bottom of an excavated hole using a 65 lb. jackhammer, had been sandblasted. (Just as if it had been prepared for patching.) It showed some very minor fractures in the cement paste (3 fine cracks, about ½" long) and in one piece of aggregate.

Core #2 – The hole had been excavated with a 35 lb. jackhammer and surface sandblasted, was observed and it had three possible areas with possible micro-cracks.

Further examination of both cores using die penetrant showed a few additional cracks in each but nothing significant.

ASTM C 856-95, *Standard Practice for Petrographic Examination of Hardened Concrete*, was followed where applicable to examine the core samples.

Visual examinations showed no more micro-cracking in the areas where a 65 lb. jackhammer was used than the 35 lb. jackhammer. These two cores were the only ones out of all the cores, approximately 20, which were taken from concrete excavated using both the 35 lb. and 65 lb. jackhammers that showed any signs of micro-cracking to the bare eye or under the microscope. The data was considered inconclusive.

February 24, 1999 - Additional cores were taken, on the same bridge being patched by maintenance forces, to get baseline data for the typical in place properties of the deck concrete.

Core #1 – (Table 2) Sound original deck concrete with Meramec gravel aggregate had a compressive strength of 8,230 psi.

After the deteriorated areas of the deck were excavated, cores #2 and #5 were taken from the patched concrete.

Core #2 - from a patch excavated with the 35 lb. jackhammer, had the top half patched using Duracal cement and gravel aggregate and the bottom half was the remaining deck, base concrete. It had a compressive strength of 6,550 psi.

Core #5 - A patch with the same type repair, using the 65 lb. jackhammer had strength of 6,970 psi.

Table 2

Strengths of In-Place Concrete
Bridge N-201, I-44 West O.R., St. Louis Co., patched by Maintenance forces using 65# jackhammers Core samples taken, 2/4/99 - tested 2/17/99, AASHTO T22-97
Sound original deck concrete with Meramec gravel aggregate Compressive Strength Core # 1: 8,230 psi
Core of patched concrete: (35# jackhammer) Compressive Strength Core # 2: 6,550 psi
Core of patched concrete: (65# jackhammer) Compressive Strength Core # 5: 6,970 psi

The direct shear strength of cores from bridge N-201 was tested using the Iowa Direct Shear Test Method to compare the strength of the bond of the patching concrete to the in place concrete which had been prepared using a jackhammer.

Core #1 – Taken in a sound area of the original concrete as a control had a direct shear strength of 850 psi.

Core #4 - A core from a patch excavated with the 35 lb. jackhammer with the top half patched using Duracal cement and gravel aggregate and the bottom half the remaining base concrete had direct shear strength of 373 psi.

Core #6 - A core with the same type repair as core #4 except using the 65 lb. jackhammer had direct shear strength of 200 psi.

The shear strength of the core from the patch prepared with the 35 lb. jackhammer was almost twice that of the one prepared with the 65 lb. jackhammer. However, no correlation between the shear strength and the destructiveness of using a 65 lb. jackhammer versus the 35 lb. jackhammer can be made unless a large number of sets of cores are tested. Additionally, it is unsure how significant the Iowa Shear Test is to test patched samples of this kind. The test, which uses a guillotine type single shearing plane, makes it hard to position the bond line of the patch exactly the same on each specimen.

Table 3

Direct Shear Strength – tested 2/17/99, Iowa Shear Test method, Bridge N-201	
In Place	Core # 1: 10,690 Lbf /π(2in)^2 = 850.68 psi
Patch w/35# hammer	Core # 4: 4,690 Lbf /π(2in)^2 = 373.22 psi
Patch with 65# hammer	Core # 6: 2,510 Lbf /π(2in)^2 = 199.74 psi

Task 4. Pull-off Tests

Pull-off testing using the ACI 503R *Soundness and Surface Adhesion Test* (ASTM C856 – 95) method was conducted on all three circumstance of Task 2:

Location 1. A bridge patched by MoDOT maintenance forces using 65 lb. jackhammers.
Location 2. A bridge patched by contractor forces in a Maintenance Repair contract.
Location 3. A bridge patched by contractor forces in a Construction Rehabilitation contract from the STIP.

An additional site was added which wasn't in the original work plan.
Location 4. A construction contract, which used hydro-demolition instead of jackhammers, for removal of deteriorated concrete.

Location 1. Bridge G-488RN, US 63, Callaway County was patched by MoDOT maintenance forces using a 35 lb. jackhammer on one area of the deck and a 65 lb. jackhammer on another on November 30, 2000 and again on June 5, 2001. First the pull-off or tensile strength of a sound area of the original deck concrete was taken as a control to compare other tests to. Next, the pull-off tests were taken on the substrate at the bottom of the hole after excavating the deteriorated concrete, (the remaining original deck concrete). The results are listed in Table 4 and Table 5.

Table 4

Bridge No. G-488RN, US 63, Callaway Co. – Dist. 5 Maintenance Repair, both 35# and 65# jackhammers – Sampled 11/30/00

Control at Curb

Location No.	Core No.	Pull Off, psi	Location of Failure
1	1	236	Bottom of core
1	2	338	1 broke at epoxy
1	3	245	1 broke in concrete
1	4	350	broke from surface

Average Pull-offs in the original good deck concrete = 292 psi

Pull-offs in Repair Patch 35# jackhammer

Location No.	Core No.	Pull Off, psi	Location of Failure
2	1	57	Broke at bond area
2	2	134	Broke at bond area
2	3	64	Broke at bond area

Average Pull-offs at excavated surface in patch using 35# jackhammer = 85 psi

Pull-offs in Repair Patch 65# jackhammer

Core No.	Location No.	Pull Off, psi	Location of Failure
1	3	126	Broke at bond area
2	3	147	Broke at bond area
3	3	102	Broke at bond area

Average Pull-offs at excavated surface in patch using 65# jackhammer = 125 psi

It can be seen that in November 2000 the pull off strength of the 35 lb. prepared area was actually lower (85psi) than the one prepared with the 65 lb. jackhammer at 145 psi. This was reversed in June 2001 with the 35 lb. jackhammer test being slightly higher than the 65 lb. Again the data was inconclusive.

Table 5

Bridge No. G-488RN, US 63, Callaway Co. – Dist. 5 Maintenance Repair, both 35# and 65# jackhammers – Tested 6/5/01

Control at Curb near E. Abutment

Location No.	Core No.	Pull Off, psi	Location of Failure
1	1	255	Broken half in concrete .and half in epoxy
1	2	235	1 Base concrete broken
1	3	306	1 Broken 2/3 in concrete, 1/3 epoxy
1	4	382	Broken 90% in concrete, 10% in epoxy

Average Pull-offs in the original good deck concrete = 295 psi

Pull-offs in Repair Patch 35# jackhammer

Location No.	Core No.	Pull Off, psi	Location of Failure
2	1	140	Broke at bond area
2	2	89	Broke at bond area
2	3	191	Broke at bond area

Average Pull-offs at excavated surface in patch using 35# jackhammer = 140 psi

Pull-offs in Repair Patch 65# jackhammer

Location No.	Core No.	Pull Off, psi	Location of Failure
3	1	83	Broken at base concrete
3	2	76	Broken 70% in concrete, 30% in epoxy
3	3	70	Broken 90% in concrete, 10% in epoxy
3	4	108	Broke 100% in concrete

Average Pull-offs at excavated surface in patch using 65# jackhammer = 84 psi

NOTE: No pull-off tests were taken through the patches on this bridge

Location 2. Pull-off test data was obtained from a maintenance contract job, J6M0030, let on April 13, 1999 (Bridge A-1270) using 35 lb. and 65 lb. jackhammers. This data was to compare with tests from decks repaired using 65 lb. jackhammer by a MoDOT district bridge repair crew (G-488RN).

Table 6

Bridge A-1270, I-64, St. Louis City – second year maintenance by contract, 35# jackhammers specified - Tested 7/7/99

Pull-offs in repair patch,

Location No.	Core No.	Pull Off, psi	Location of Failure
1	1	197	
1	2	108	
1	3	96	
2	2	45	* (5 holes drilled, 3 broke off)
2	3	22	
3	1	146	* (4 holes, 1 broke off)
3	3	95	
3	4	166	
Average Pull-offs in repair patch = 110 psi			

Location 3. A bridge patched by contractor forces in a Construction Rehabilitation contract from the STIP, Bridge No. A-241W, job number J6I0945B, Route I-270, St. Louis County was tested to complete the comparisons as set out in Task 2. These tests are listed in Table 7.

Table 7

Bridge No. A-241W, I-270/Bellefontaine Rd., St. Louis Co. – Construction Project J6I0945B (Bridge Rehabilitation), 35# jackhammers

Pull-offs of Original concrete after milling - sampled 12/2/99

Location No.	Core No.	Pull Off, psi
1	1	235.67
1	2	96
1	3	96
1	4	83

Average Pull-offs of Original concrete after milling = 128 psi

Pull-offs of Base Concrete in Bottom of Patch - sampled 12/2/99

LocationNo.	CoreNo.	Pull Off,psi	Location of Failure
2	1	83	
2	2	102	
2	3	*	* - Knocked over and broken by tester
2	4	148	

Average Pull-offs of Base Concrete in Bottom of Patch = 111 psi

Pull-offs same locations as above after patched. – sampled 5/24/00

Location No.	Core No.	Pull Off, psi	Location of Failure
1	1	32	@ interface of overlay & org. deck, (no patch-2"silicafume (sf) overlay)
1	2	127	broke at interface with 2" thick sf, no patch
1	3	38	concrete broke in orig. concrete-1 7/8" thick & patch 2 1/4" thick
1	4	121	broke at epoxy on surface, (2" thick sf & 2 1/4" thick patch)
2	5	115	broke @ interface very smooth-2 1/16" thick sf overlay
2	6	127	broke @ interface w/deck, interface rough, (2 1/2" thick sf)
2	7	178	broke 100% interface w/org. deck interface smooth surface-2 1/16" sf overlay

Average Pull-offs of Base Concrete in Bottom of Patch = 105 psi

It should be noted that because of the roughness of the test surface left by milling on bridge A-241W (construction contract) and by jackhammers on all three bridges that the ASTM specified testing apparatus probably underestimated the actual tensile strength of the substrate concrete. Because it is hard to get a completely flat surface to place the base of the test machine on, a directly normal (90^o) pull-off angle was hard to obtain. Sometimes in the excavated areas the base of the tester had to be placed against rebar or leveled with shims of some kind. During the summer of 2000, the test apparatus was modified from drawings obtained from the Virginia DOT with a swivel at the pulling head but this did not seem to improve the accuracy much. This undoubtedly caused lower than actual tensile strength values. This can be seen in the data from Table 4 and Table 5. The very high values obtained on the control tests taken on the level, good quality, in place concrete on the shoulder of bridge G-488RN were 292 psi and 295 psi compared to the 80-140 psi in excavated areas.

Location 4. Additionally, pull-off tests were taken to compare the bond strength of jackhammer preparation compared to data from another research project on hydro-demolition repair done by construction contract on Bridge A-174W, I-44, Greene County. That data is recorded in Table 8.

It had been proven in two previous maintenance operations in District 6, that hydro-demolition can provide a good surface to put a deck overlay on and be done in a significantly shorter time frame than conventional jackhammer concrete removal. Hydro-demolition was used in one of these projects for maintenance patching and tripled production repairing six bridge decks. These projects did point out that there are limitations to using hydro-demolition depending on the type of structure, need for traffic control and environmental concerns due to water runoff.

Table 8

Bridge No. A-174W, I-44, Greene Co. – Construction Project J8I0647
(Bridge Rehabilitation) Hydro-blasted deck (15# jackhammer used if necessary to clean up edges) **and Latex Overlay – Sampled** 7/16/99

Pull-offs on Hydro-blasted deck

Location No.	Core No.	Pull Off, psi	Avg. Pull Off, psi	Location of Failure
1	1	57		100% in base
1	2	325	172	100% in base
1	3	134		100% at interface
2	1	108		100% at interface
2	2	166	104	Not recorded
2	3	38		
3	1	102		100% in base
3	2	134	180	100% in base
3	3	306		100% in base

Average Pull-offs of Hydro-blasted deck and Latex Overlay = 152 psi

Conclusions

Task 1 Comparing MoDOT's requirements with eight other states and the American Concrete Institute standards, using lightweight jackhammers in the 30-35 lb. range for construction repairs is what is preferred by all of those surveyed.
As far as jackhammers used for maintenance repairs, the 65 lb. jackhammer is about the average used in all the states except Iowa and the ACI recommendation.

Task 2 Observation of procedures for removing deteriorated concrete on bridge decks showed specifications are being followed substantially on both maintenance and construction projects. Operators tend to use the heaviest jackhammers they can before switching to a chipping jackhammer around the exposed rebar. Hitting (ringing) the rebar with a heavy jackhammer does carry the stresses further into the good concrete.

Task 3 Visual examinations showed no increased micro-cracking in the areas where a 65 lb. jackhammer was used than the 35 lb. jackhammer. Only two (2) cores out of twenty (20), which were taken from concrete excavated using both the 35 lb. and 65 lb. jackhammers, showed any signs of micro-cracking to the bare eye or under the microscope. The data suggested the size of jackhammer, at least up to the 65 lb. range, did only minor damage to the remaining concrete. This verifies that MoDOT has made the right decision to use the 65 lb. or below class jackhammers. The fact that two specimens did have micro-cracking, however, shows that damage still is being done when correct jackhammering procedures aren't followed or rebar "ringing" is allowed. Eliminating all cracking in the remaining concrete is critical, especially on bridge rehabilitation projects which are expected to last at least 20 years, to be sure that the concrete patch filling the hole stays well bonded.

Task 4 There was no significant difference in the pull-off test results between the areas prepared with a 35 lb. jackhammer and a 65 lb. jackhammer shown by our testing. The average tensile strength was in the range of 125 psi for pull-off of the patches. It was hoped that an average around at least 150 psi or better would be obtained. The pull-off data that was acquired in the last two years, and presented in this report, is considered to be inconclusive. Even so, for bridge rehabilitation projects, there is enough data from American Concrete Institute and from other state DOT's to point at specifying no more than a 35 lb. maximum jackhammer.

Pull-offs from the hydro-demolition on Bridge A-174W are included for comparison to the jackhammer repairs and although they averaged 150 psi, it was hoped they would have been much higher (say 200psi). The data obtained in this study about hydro-demolition was not significantly better than for conventional removal, however, data was only available for one hydro-blasted bridge at this time. It is believed that future hydro-demolition on bridges will show that it is preferable to use no jackhammers at all.

Recommendations

1. It is recommended MoDOT stay with the present special provision limiting jackhammers to a maximum 35 lb. for rehabilitation projects. These bridge decks are given a dense concrete overlay and expected to extend the life of the bridge at least 20 years. This is in line with ACI recommendations and other state specifications.

2. It is recommended that specifications for contract maintenance repair of bridges be changed back to the original ones used in 1998 to allow the 65 lb. jackhammer.

   The bridges in these contracts are maintenance problems and are being patched only to allow a smoother riding surface. Most of these decks have a NBIS rating of less than 6, which MoDOT policy requires be replaced and not eligible for rehabilitation anyway. It is recommended to restore the 65 lb. jackhammer in order to accomplish patching in a more timely manner.

3. Section 10.18.3 of the MoDOT Maintenance Manual allowing 65 lb. jackhammers being used by MoDOT crews should remain as is.

4. MoDOT should promote the use of hydro-demolition over conventional jackhammer removal of concrete wherever it is not limited by project or structure oriented restraints.

Implementation Plan

It is recommended that future patching projects let by maintenance contract on bridges that have an NBIS Deck Rating of less than 6 allow the use of 65 lb. jackhammers as they did in the first projects let in 1998. Additionally MoDOT maintenance forces should continue following the procedures set out in the MoDOT Maintenance Manual.

Bridges let for rehabilitation by construction contract should continue to use the current job special provision requiring no greater than a 35 lb. jackhammer be used for deck repair. Research in other states also shows good results using hydro-demolition, and as hydro-demolition equipment becomes more available MoDOT should encourage its use for deck preparation wherever possible.

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Lucy Smith – Senior Construction Inspector, District 6 MoDOT

Implementation Objective

The objective of this implementation plan is to get the best final product for rehabilitated bridge decks. It has been shown in other public and private projects that hydro-demolition, depending on the type of superstructure and layout of the bridge, is the preferred means to obtain a good sound substrate for patching and/or overlaying a bridge deck. Hydro-demolition has been shown to save in upfront cost during construction and also in the long term in life-cycle cost.

The objective for bridge repair is to provide the most cost-efficient and timely manner to get the bridges repaired and reopened to traffic. Use of 65 lb. jackhammers, which could not be shown to do significantly more damage, should be used for these temporary repairs to save money for deck or bridge replacements in the future.

Affected Business Units and Principal Contact

MoDOT business units of Bridge and Project Development should look for opportunities to use the less destructive method of hydro-demolition on future bridge rehabilitation projects where project conditions allow it.
State Bridge Engineer – Shyam Gupta

Project Development and the districts should go back to specifying 65 lb. jackhammers for maintenance contract bridge repair projects.
State Bridge Maintenance Engineer – Jim Carney

Maintenance and district bridge repair crews should continue using 65 lb. jackhammers as specified by the Maintenance Manual.

Implementation Period

The objectives of this investigation should be implemented immediately both for repair and rehabilitation of bridge decks.

Each district should be able to let at least one project in the coming construction season which specifies the use of hydro-demolition. (More hydro-demolition contractors are already moving into the Missouri area and additional jobs will bring down high mobilization costs experienced in the past.)

Funding

There should be none or minimal increases in bridge deck rehabilitation costs. Utilizing hydro-demolition on appropriate projects should not increase significantly the bid item for deck repair and it may actually go down or be offset by other bid items. (Cost of making patches at the same time as overlaying reduces several construction steps and should reduce deck repair prices and possibly overlay prices.)

Cost for deck repair on maintenance contracts should stay the same or go down because the contractor will bid expecting to use 65 lb. jackhammers.

Maintenance crew costs should not be affected. (Requiring them to go to 35 lb. jackhammers, however, would have slowed down operations and increased costs significantly.)
Use of hydro-demolition for quick repair of several bridges has been shown by District 6 Maintenance to take a third of the time as normal jackhammer repairs, freeing the crew to accomplish more bridges patched.

Technology Transfer

A Technical Brief on the Effects of Heavyweight Jackhammers or a copy of this full report is available from the Research, Development and Technology Unit (RDT).

The Bridge Maintenance Unit made a video available on hydro-demolition that was sent to all district Maintenance offices. This video should be available to all district Project Development staff or a copy can be obtained through RDT.

Procedure

1. If the recommendations of this study are accepted, Maintenance contracts for deck repair should be monitored to see that they are specifying the larger 65 lb. jackhammers be used on these projects for the 2002 construction season. The RDT unit should be notified of any problems.

2. Rehabilitation construction contracts should be monitored in each of the ten districts in the 2002 construction season to see if at least one project has used hydro-demolition and to do some additional monitoring and testing by RDT staff.

Budget

A minimal budget is necessary for any additional monitoring. If problems are investigated on maintenance jackhammer repair RDT personnel will do them on an as needed basis.

Construction or maintenance personnel should do monitoring of hydro-demolition projects during the job. The RDT bridge deck survey crew can probably accomplish any pull-off testing if the district notifies them when hydro-demolition will be performed.

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SHRP-S-336, Techniques for Concrete Removal and Bar Cleaning on Bridge Rehabilitation Projects - Michael C. Vorster, James P. Merrigan, Robert W. Lewis, Richard E. Weyers, Virginia Polytechnic Institute & State University, The Charles Edward Via, Jr. Department of Civil Engineering, 200 Patton Hall, Blacksburg, VA 24061-0105; Strategic Highway Research Program, National Research Council, Washington, D.C. 1992

RI97-025, Hydro-demolition and Repair of Bride Decks – John D. Wenzlick, P.E.

Appendix A
Research Work Plan

Research Work Plan
(Revised May 25, 1999 – all revisions are Underlined)

Date: 5/11/98

Project Number: RI98-021

Title: Heavyweight Hammer

Research Agency: Missouri Department of Transportation, Division of Research, Development and Technology

Principal Investigators: J.D. Wenzlick

Objective:

The purpose of this study is to determine if specifying a heavyweight jackhammer (65 lb.) for bridge deck repair will be detrimental compared to the current construction project special provision that specifies a 35 lb. jackhammer. We will try and determine if there is more damage caused to the remaining concrete, either around the perimeter of the patch or adjacent to the rebar running into the remaining concrete, by using the heavier jackhammer during concrete removal.

Background and Significance of Work:

Because of the large number of deck repairs needed in the St. Louis area a Maintenance project, J6M0007, was let on March 25, 1998 to repair up to 160 bridges within the I-270 loop in St. Louis and St. Louis County. A heavy weight jackhammer, 65 lb., was specified as is used by the local maintenance crews (specified by section 10.18.3 of the MoDOT Maintenance Manual) instead of the regular Bridge Division JSP, *Repairing Concrete Deck,* which specifies a 35 lb. jackhammer.
Additionally because of the need to get the lanes opened to traffic the same day Duracal cement was specified for patching material versus B1 or B2 bridge concrete.

Action Plan:

1. Observations will be made on job J6M0007 as well as on a maintenance contract on Rt. 17, Pulaski County, J9M0002, or a construction project on I-44, St. Louis County, J6I0617D, to compare the repair operations under different specifications and conditions.:

A. J6M0007 used the Maintenance specification of 65 lb. jackhammers and patching concrete using Duracal cement.

B. J9M0002 used the *Repairing Concrete Deck* JSP with B-2 concrete with the option of Type III Cement used to accelerate the set. Type III cement was not used for patching. so RDT did not observe this work.

C. J6I0617D had the same JSP as (B.) above but used regular cement since there are no restrictions on opening to traffic. RDT did not observe this work.

D. A construction project will be found in 1999 to substitute for the conditions of parts B. and C. above documenting the use of the 35 lb . jackhammer. (This was project J6I0945B, Route I-270, St. Louis County.)

2. Additionally 4" diameter cores will be taken around the edges and on top of a rebar in the sound concrete near a patched area on all of the projects if possible. The cores will be examined for any micro-fracturing that may have occurred during concrete removal with the jackhammers, to see if damage is worse with the 65 lb. versus the 35 lb. jackhammer. No cores were taken after removal of concrete using 65 lb. jackhammers before patched with concrete in 1998 on project J6M0007. Cores were taken in early 1992 through the patches into the base concrete and around the perimeter of the patches on bridge N-201 WBL and also where exposed rebar was impacted by the 65 lb. jack jackhammer.

Literature Search: As required if concrete samples are studied at the Materials Laboratory. Did a TRIS database search, looked at SHRP and ACI guidelines, and contacted surrounding states about their procedures.

Method of Implementation: When all testing is completed we will report any new findings state wide and work towards applicable changes to the specifications if called for.

Research Period: This evaluation will begin with the field inspection scheduled to start May 6, 1998. It is anticipated all testing and reporting done as of December 1, 1998. Testing and reporting was not completed until 2001.

Funding: This project will be fully funded by MoDOT. Charges will go to the Research Investigation number assigned (906 RDT RI98 021 N).

Research Work Plan and Supporting Data

Procedure:

May 6 - field inspection scheduled on job J6M0007 in St. Louis on the first bridge being repaired, A-839R, Jefferson Ave./ I-64.

June 1-5 - obtain 2-4 cores from above bridge, A-893R, on job J6M0007 before overlay applied. No cores taken on this project, but took 4" cores adjacent to and thru rebar (core outside negative moment areas) to inspect for micro-cracking.
- observe concrete removal and repair on J6I0617D, I-44, St. Louis Co., and obtain cores if possible. Did not observe this project but did observe project J6I0945B, Route I-270, St. Louis County.

July 6-10 - observe concrete removal and repair on J9M0002, Rt. 17, Pulaski County and obtain cores if possible Did not observe this project.

July 27-31 - prepare cores and observe in microscope to determine if micro-fractured or not and extent. Compare cores from each of three (3) jobs.

February 2 & 17, 1999 - obtained cores from Bridge N-201 WBL being patched by the District 6 bridge repair crew. Took 2 cores in repair area using a 65 lb. jackhammer and 1 core in area using 35 lb. jackhammer.

Aug.-Sept.- schedule any additional observations and coring needed due to findings so far. Examine additional cores in lab

Summer 1999 - prepare cores and observe in microscope to determine if micro-fractured or not and extent from both a construction project and from a maintenance contract such as J6M0030 to be let on 4/13/99. Compare with cores from decks repaired using 65 lb. jackhammer by a district bridge repair crew.

- take pull of strengths
- take 4" cores for testing of compressive and shear strength.

October - prepare and present report. Modify or rewrite and prepare final report.
Final report was prepared in August –July 2001.

Staffing: J.D. Wenzlick will be the principal investigator, Nelson Cook or J.D. Wenzlick will perform microscopic evaluations. A crew of 2-4 technicians will be required to obtain concrete samples from the bridge and one technician may be used for specimen preparation in the lab.

Equipment:

RDT Drill Truck (including core drilling equipment).
Traffic Control - will try to coordinate with contractor's lane closures other wise will provide our own.
1- Sign Truck
1 - Crash Truck

- General laboratory equipment at Central Laboratory in Jefferson City.

Budget:

Personnel:		
Research Director - 2 days x (8hr. x $24.98/hr. x1.75 add.) = (field visit and administration)		$ 700
Senior Research Development Engineer - 30 days (8 x $22.18 x 1.75) = (field visit, coring, reporting)		$ 9,300
Field Testing Technician - 2 days x (8 x $15.54 x 1.75) = (lab work and reporting)		$ 440
3 Testing Technicians - 20 days x (8 x $12.75 x 1.75) = (coring, sample preparation)		$ 10,700
	TOTAL	$ 21,140
Equipment Rental:		
1 ton Pickup - (3 trips) 260 miles x $ 0.434/mi. =		$ 340
Sedan - (3 trips) 260 x $ 0.19 =		$ 150
3/4 ton Pickup - (3 trips) 260 miles x $ 0.389/mi. =		$ 300
HD Dump - (3 trips) 260 miles x $ 0.656/mi. =		$ 500
	TOTAL	$ 1,290
	Grand TOTAL	**$ 22,430**

Appendix B

Construction Contract Job Special Provision (Bridges)
REPAIRING CONCRETE DECK –
As used on, Project J6I0945B I-270, St. Louis County, Bridge No. A-241W

REPAIRING CONCRETE DECK JSP 03/22/01

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 [6 mm] deep as specified in section 505.

Slight deck imperfections of no more than 1/2 inch [13 mm] 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 [13 mm] 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 requirements 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 [19 mm] 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 [19 mm] clearance shall be required.

The deteriorated concrete shall be removed as required to provide 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 psi [22 MPa] 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 [0.4 square meters] in size and the total repair within a "Special Repair Zone" does not exceed 12 square feet [1.1 square meters], 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 [0.8 square meters] in size and the total repair within a "Special Repair Zone" does not exceed 27 square feet [2.5 square meters], 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 [450 mm] 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 [22 megapascals]. 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 Requirements

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 [15.9 kilogram] class may be used for concrete removal and chipping jackhammers of the 15 pound [6.8 kilogram] 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 [110 MPa]. 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. Deck drains receiving runoff from the contractors operation shall be temporarily plugged and the discharge water shall not be released from the site until the broken concrete, aggregate and other settleable solids have been removed through filtration, sediment basins, or other effective best management practices as approved by the engineer. Hydro demolition shall not impede or interfere with traffic being maintained in the vicinity of the work. Heavy equipment, such as vacuum trucks for removal of concrete debris, shall not be permitted to place wheel loads on the deck areas where deteriorated concrete has been removed.

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 [7 mm] 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 [22 MPa]. Type III cement may be used to accelerate the set. The coarse aggregate shall be Gradation E, Sec. 1005.1.3.

Accelerating additives containing chlorides will not be allowed.

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 [22 MPa]. Type III cement may be used to accelerate the set. The coarse aggregate shall be Gradation E, Sec. 1005.1.3.

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 [2.97 kilograms per cubic meter], 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" [19 mm] 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 [2.97 kilograms per cubic meter], 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 [22 MPa]. Type III cement may be used to accelerate the set. The coarse aggregate shall be Gradation E, Sec 1005.1.3. 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 [0.1 square meter] 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 [0.1 square meter] of that part of the existing deck area replaced with new concrete from the bottom of the deck up to 1/4 inch [7 mm] 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 [0.1 square meter] 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 [square meter] or "Full Depth Repair" per square foot [square meter].

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

Appendix C

Maintenance Manual Section 10.18.3

10.18.2 BRIDGE DECK MAINTENANCE

10.18.2.1 GENERAL

The maintenance of bridge decks must be timely and performed to a high standard to prevent further deterioration and to protect the investment. Repair of holes or deterioration must be done immediately and not delayed for approval at the time of the annual bridge inspection. Bridge decks that present unusual problems shall be brought to the attention of the division office since it may require the assistance of division bridge maintenance crews or contract repair.

Bridge deck maintenance is generally in the following categories:

1. Cleaning and flushing dirt, debris, and snow and ice control chemicals which retain moisture and accelerate deck deterioration.
2. Bituminous seal coats or linseed oil treatment to minimize deck wear and assist in preventing further deterioration or possible damage from ice control chemicals. Seal coats must be approved by the division office.
3. Bituminous mat overlays are used to level uneven decks. This work may be performed by maintenance crews or by contract and must also be approved by the division office. Repairs to these mats must be made with materials similar to the original material, that is, asphaltic concrete mix must be used to patch or repair asphaltic concrete mats except for temporary repairs in an emergency. It is desirable to place a seal coat or double seal coat to waterproof the deck before placing a mat overlay.
4. Resurfacing with concrete or replacement or patching of concrete floors is performed by district crews or by contract. Asphaltic materials should not be used for making permanent repairs in concrete decks.
5. Repair or replacement of timber decks may be performed by district crews or division bridge maintenance crews.
6. Epoxies may be used for sealing cracks. Accelerated concrete, epoxy mortar and micro-cements may be used for patching holes or spalled areas. This work should be performed by district crews trained in the use of these materials by division bridge maintenance personnel.

10.18.3 CONCRETE DECK REPAIRS

Concrete deck repairs range from crack sealing to full depth repairs. Emergency partial depth repairs may temporarily be made with bituminous materials. Permanent repairs should be scheduled as soon as possible. Full depth failure should be repaired immediately. In an extreme emergency, where traffic or weather condition make it impossible to do this, the short term use of steel plates is acceptable. They must be anchored securely to the deck and appropriate signing erected.

Failures less than 1 inch deep are called spalls. Failures over 1 inch deep but that do not go through the deck are classed as partial depth.

Partial and full depth repairs are made with concrete, or approved accelerated mortars.

Concrete repairs of full or partial depth failures may be made with high early strength cement or approved quick setting cement concrete, such as duracrete.

Spalls are repaired using partial depth methods or they may be filled with approved polymers or latex modified asphalt emulsion mixes.

Regardless of the permanent patching material to be used, the procedures are basically the same. The area around the failure should be sounded to determine the limits of the failure. The area should be marked and sawed with a concrete saw. Care must be taken not to cut the reinforcing steel. On a deck with an asphaltic overlay, it should be removed wider than the deck area to be patched. The patch can then be finished smooth and flush with the deck and the overlay properly compacted.

Voids tubes of voided slab bridges which are opened during concrete removal shall be formed to prevent filling the void tube with patching material. The division office may be contacted for assistance in forming methods.

The total deck repairs made to bridges with concrete superstructures (main supporting element for span) such as voided slabs, concrete box girders, concrete girders, etc., shall be limited to 100 square feet per span per day. This shall also apply to culverts. This limit does not apply to bridges with steel superstructures. If extensive repairs are required, a special repair plan should be requested from the assistant division engineer - bridge maintenance.

A 65 pound class breaking hammer is to be used to remove the broken and deteriorated concrete to a depth below the top reinforcing steel. Loose concrete and pack rust shall be cleaned from exposed steel. All loose material is to be removed from the hole and fine particles blown out with compressed air. Additional reinforcing steel may be added where needed.

The patching material is mixed, placed and finished according to accepted procedures or manufacturer's recommendations.

Care must be taken to assure the patch has gained sufficient strength before traffic is allowed on it. Pavon should be used to seal patch edges. The asphalt overlay is replaced after the repaired deck is primed and waterproofed with liquid asphalt. SS-1, CSS-1, EA90P, CRS-2P, or pavon is recommended for this waterproofing.

Full depth repairs in the decks of precast concrete slab spans shall be made in the same manner as the decks of other span types. Only the deck is to be repaired. The deck shall be that concrete above the plane of the bottom of the slab. The repair shall extend the full width of the panel over both stems. See Figure 10.13.

If slab reinforcement in precast concrete slab panels must be replaced, use #3 or #4 bars at the same spacing as existing reinforcement. If it is necessary to splice longitudinal slab reinforcement, use a 12 inch lap splice.

Should the stems of precast concrete slab panels have shear cracks he ends of panels, the division office should be contacted before repairs are attempted. See Figure 10.13.

10.18.4 SEAL COAT RESURFACING

If the condition of the deck is such that deterioration is not advanced and the deck is not uneven, an asphaltic seal coat or double seal coat may be applied. See "Planning Guides", function 482 of the "Maintenance Planning Manual" for additional information. Bridge deck seal coats should be performed during the summer months and be completed by September 1.

The deck should be repaired prior to sealing in accordance with the procedures outlined previously for concrete repairs.

The entire deck should be cleaned by sweeping and/or flushing thoroughly and allowed to dry completely prior to sealing.

The bituminous material shall be EA90P or CRS-2P liquid asphalt for bridges on all routes. It is permissible to use No-Strip with these asphalts. The asphalt shall be applied to the entire deck at the necessary application rate which is normally 0.3 to 0.4 gallon per square yard. The interiors of curb outlets should be sprayed thoroughly with asphalt and it is not objectionable to apply asphalt to the vertical faces of the curbs. Care must be taken not to spray asphalt on any steel members. All expansion joints should be covered prior to sealing. Tar paper should be used to provide a neat beginning and ending of the seal.

The cover material shall be Iron Mountain Trap Rock, Joplin chat or similar material approved by the division office. The gradation shall be: 100% passing 1/2" sieve, 95-100% passing 3/8" sieve, 0-10% passing #4 sieve, and 0-1% passing #200 sieve. Requisitions for this aggregate shall be submitted to the division office by the due date in Section 13.

The cover material should be applied immediately after the asphalt and rolled. The application rate should provide a single rock thickness. It is not to be applied in the curb outlet, or for a distance of two feet from the vertical face of the curb.

Traffic is to be maintained at all times. The seal coat area is to be kept barricaded to traffic for a sufficient period to allow proper curing.

Before opening the lane to traffic, all excess cover material should be removed from the deck. A day or two later, it will be necessary to again remove the excess aggregate from the deck, chords and substructure caps. Any excess oil (bleeding) should be blotted with sand or cinders immediately.

If the approaches have been resurfaced with mat, patched or are in a deteriorated condition, they should be sealed at the same time as the bridge deck to present a good appearance. Concrete or mat approaches should also be sealed at the same time when doing so will reduce traffic impact to the bridge.

Appendix D

Maintenance Deck Repair (Special) –

As used in 1998 Project J6M0007

F. MAINTENANCE DECK REPAIRS (SPECIAL)

There are several structures which are to be designated as bridges to be sounded and patched out. This shall include:

A-839R	Jefferson/I-64 (to be resurfaced by others)
A-1232R	Lemay Ferry/I-255 (to be milled and resurfaced by others)
A-1049	Olive/I-270 (to be resurfaced by others)

The above bridges are to be patched out for seal coating and/or overlaying with asphalt. The deck repairs on these bridges are to be completed by August 1, 1998. The seal coat and overlay work shall be performed by others. Other structures may be added to this list by mutual concurrence of the contractor and the engineer.

The work shall consist of all equipment, material, and labor necessary to repair designated areas of bridge deck by the methods outlined in these provisions. This shall include all jackhammers, compressors, patching material, incidental materials, equipment, etc.

Upon closing a lane, the area of concrete deterioration shall be sounded and marked by the contractor with the approval of the engineer. The limits of concrete repair shall be saw-cut generally square approximately one inch in depth. Care shall be taken not to disturb or damage reinforcing steel. Deck repairs to bridges with steel girder superstructures (plate girders, I-beams), will have unlimited repair quantities. In order to maintain the structural integrity of concrete box girder and voided slab bridges deck repairs shall be limited to designated repair zones as directed by the engineer. Bridge plans required for deck repairs on existing box girder and voided slab bridges are available in the district office.

A maximum 65 pound class breaking hammer shall be used to remove all deteriorated concrete. All remaining sound concrete shall be removed to a depth at least 3/4 inch below the top bar in the top mat of reinforcing steel. For lower bars in the top mat, if the bond is broken between the existing concrete and reinforcing bar, or more than half of the bar diameter is exposed, the adjacent concrete shall be removed a minimum of 3/4 below the bar to permit bond to the periphery of the bar. The sidewalls shall be chipped square and all corners clearly defined. The contractor shall use extreme caution on repair areas located in the negative moment area. The contractor shall not be required to achieve the 3/4 inch clearance under the large, longitudinal bars, as long as the existing concrete in the region is sound. The contractor shall carefully chip, with maximum 35 pound hammers, to the bottom of the bar to expose the majority of the bar surface area for bond. Transverse bars which have not lost their bond with existing sound concrete or been exposed over half of the bar diameter, shall not be disturbed. Otherwise, 3/4" clearance shall be achieved. Care must be exhibited in working around rebar so as to minimally disturb any reinforcing steel. All loose concrete shall be removed and pack rust shall be removed from existing reinforcing steel by wire brushing. No sandblasting or bonding agents will be required. Immediately before placing any patch material, the hole shall be thoroughly blown out with clean compressed air, with no oilier working in conjunction with the clean air line. As an option to the conventional hand/mechanical equipment listed above, the contractor will be allowed to remove concrete and asphalt to the top of the reinforcing steel with a cold milling machine.

Where section loss in reinforcing steel is in excess of 50% of the total bar diameter, additional steel of the same bar diameter shall be furnished and spliced in by the contractor. The lap shall be 24 bar diameters where the splice length can be achieved. Where necessary, bar supports shall be inserted. No direct pay will be made for any materials or labor necessary for furnishing or installing reinforcing steel.

Concrete for repairing concrete decks shall be a mix utilizing Duracal cement (U.S. Gypsum). All materials shall conform to Division 1000, Materials Details, unless otherwise noted.

Duracal cement shall be as manufactured by U.S. Gypsum or approved equal. Fine aggregate shall meet requirements of Section 1005.2 for concrete construction. Coarse aggregate shall be 1/2" roof gravel meeting the quality requirement of 1005.1. The contractor may submit an alternate design or an alternate quick set material for consideration as a patching material. Bagged "Duracrete" shall not be used.

For a mix utilizing approximately 1.07 cu. ft. of Duracal concrete, the following proportions apply:

Duracal Cement	50.0 lbs.
Coarse Aggregate (1/2" roof gravel)	50.0 lbs.
Fine Aggregate	50.0 lbs.
Potable Water (1 3/4 gal.)	14.6 lbs.

For Duracal concrete, the mix procedure shall be as follows:

1. Introduce measured amount of water to mixer.
2. Add approximately one-half of the aggregate
3. Mix briefly (30-60 seconds).
4. Add Duracal cement with mixer operating.
5. Add remainder of aggregate.
6. Mix until lump free, but less than five minutes.
7. Batch, place, and finish.

Material may be batched from a calibrated mobile type mixer or hand mixer. The patch area shall be pre-dampened before the patch material is placed. No water shall be used to finish off the top of the patch.

The concrete patching material shall be consolidated, vibrated and screeded, and in the final stages of set, troweled to a smooth finish. Concrete mixtures shall be placed at a maximum 3 1/2 inch slump. No texturing will be required. Concrete mixes shall obtain the minimum time set requirements as shown below, before opening to traffic.

Temperature	Minimum Set Time
Over 70 degrees	2 1/2 hours
55 to 70 degrees	3 hours
Less than 55 degrees	3 1/2 hours

In the event of an ambient temperature below 40 degrees, insulating mats shall be placed on the patches during the set period. No patch material shall be placed when the forecast temperature is 35 degrees or less.

No curing will be required, however all patch edges shall be sealed off with a state furnished liquid sealer - "Pavon". The "Pavon" shall be coated with a light colored sand provided by the contractor to prevent tracking and to blend in with the existing deck.

No control cylinders will be cast by MoDOT, except possibly for informational purposes for the department's use.

Minor "punch throughs" less than one square foot in the deck will not constitute full depth repair. These areas, however, must be adequately sealed off prior to pouring concrete. Voided tubes shall be repaired in a manner so that the tube shape is basically maintained and such that no patch material fills the void. The contractor shall use extreme caution to limit minor failures due to jack hammering.

The payment for maintenance deck repair will include all labor, material, and equipment necessary to complete the work. The accepted quantities of Maintenance Deck Repair will be field measured to the nearest tenth of a square foot for each individual patch. The total amount of deck repair will be paid for at the contract unit price per square foot, item no. 613-99.00. Full-depth repair is not anticipated, but if encountered, it will be paid for as twice the maintenance deck repair price. In addition, repairs required to the top riding surface of the abutment back wall shall be paid for as full depth repair.

Appendix E

BRIDGE DECK REPAIR (SPECIAL) -

As used in 1999 Project J6M0030

[Revised – limited to use of 35 lb. Jackjackhammer)

M. BRIDGE DECK REPAIR (SPECIAL)

This work shall consist of all equipment, material, and labor necessary to repair designated areas of bridge decks using the methods and materials outlined in these provisions.

Preparation Of The Repair Area (Partial Depth)

Upon closing a lane, the bridge deck shall be sounded to identify areas of concrete deterioration and delamination. Areas identified for repair shall be marked by the contractor with approval of the engineer. Deck repairs on bridges with steel girder superstructures (plate girders,

I-beams), may have unlimited repair quantities per span. In order to maintain the structural integrity of concrete box girder and voided slab bridges, deck repairs shall be limited to designated repair zones as directed by the engineer. Bridge plans required for deck repairs on box girder and voided slab bridges will be provided by the engineer upon request.

The limits of concrete repair shall be saw-cut generally square approximately one inch in depth. Care shall be taken not to disturb or damage reinforcing steel. A maximum 35 pound class chipping hammer shall be used to remove all deteriorated concrete. Hammer bits shall be sharp to reduce pounding. All remaining sound concrete shall be removed to a depth at least 3/4 inch below the top bar in the top mat of reinforcing steel. For lower bars in the top mat, if the bond is broken between the existing concrete and reinforcing bar, or more than half of the bar diameter is exposed, the adjacent concrete shall be removed a minimum of 3/4 inch below the bar to permit bonding of the patching material to the bar. The sidewalls shall be chipped square and all corners clearly defined.

The contractor shall use extreme caution on repair areas located in the negative moment area of the deck as directed by the engineer. The contractor shall not be required to achieve the 3/4 inch clearance under the large, longitudinal bars, as long as the existing concrete in the region is sound. The contractor shall carefully chip to the bottom of the bar to expose the majority of the bar surface area for bond. Transverse bars which have not lost their bond with existing sound concrete or been exposed over half of the bar diameter, shall not be disturbed. Otherwise, 3/4 inch clearance shall be achieved. Care shall be exhibited in working around rebar so as to minimally disturb any reinforcing steel.

Minor "punch throughs" of the deck by hammer bits (less than one square foot) will not constitute a full depth repair. These areas, however, must be adequately sealed off prior to pouring concrete. Voided tubes shall be repaired in a manner so that the tube shape is basically maintained and such that no patch material fills the void. The contractor shall use extreme caution to limit minor failures due to jack hammering.

Immediately before placing any patch material, the hole shall be thoroughly blown out with clean compressed air, with no oiler working in conjunction with the clean air line. No sandblasting or bonding agents will be required. All loose concrete and pack rust which remains shall be removed from the existing reinforcing steel by wire brushing or other method approved by the engineer. The contractor shall use care to not create a traffic hazard with large amounts of airborne dust or debris.

As an option to the conventional hand/mechanical methods detailed above, the contractor may, with approval of the engineer, remove the deteriorated concrete to the top of the reinforcing steel by cold milling.

Preparation of the Repair Area (Full Depth)

For bridge deck repair areas requiring full depth repairs, the contractor shall exercise caution to minimize overbreak of the bottom of the slab adjacent to the repair area. The bottom of the repair area shall be formed and properly supported to prevent sagging of the poured patch. On bridges over other roadways, the forms shall be removed after the patch has sufficiently cured. Bridges over streams will not require removal of the forms.

Additional Reinforcing Steel

If section loss in the existing reinforcing steel is in excess of 50% of the total bar diameter, or if, in the judgment of the engineer, the amount of section loss is critical to the integrity of the bridge deck, new epoxy coated reinforcing steel of the same bar diameter shall be furnished and spliced in by the contractor. The amount of additional reinforcement required will be as directed by the engineer. The lap shall be 24 bar diameters where the splice length can be achieved. Where necessary, bar supports shall be inserted.

All work involving epoxy coated reinforcing steel shall comply with Section 710 of the Standard Specifications. Due to the small amount of material estimated to be required, the contractor will not be required to have the material inspected by the Commission, but shall provide certification of compliance with Section 1036 of the Standard Specifications.

Patching Material

Concrete for repairing bridge decks shall be a mix utilizing Duracal cement or an approved alternate patching material. The contractor may submit an alternate mix design or an alternate quick set material for consideration as a patching material.

If Duracal cement is used it shall be as manufactured by US. Gypsum or approved equal. All materials shall conform to Division 1000 of the Standard Specifications unless otherwise noted. Fine aggregate shall meet the requirements of Section 1005.2 for concrete construction. Coarse aggregate shall be 1/2" roof gravel meeting the quality requirement of 1005.1.

For a mix utilizing approximately 1.07 cu.ft. of Duracal concrete, the following proportions apply. Bagged "Duracrete" shall not be used:

Duracal Cement	50.0 lbs.
Coarse Aggregate (1/2" roof gravel)	50.0 lbs.
Fine Aggregate	50.0 lbs.
Potable Water (1 3/4 gal.)	14.6 lbs.

For Duracal concrete, the mix procedure shall be as follows:

1. Introduce measured amount of water to mixer.
2. Add approximately one-half of the aggregate
3. Mix briefly (30-60 seconds).
4. Add Duracal cement with mixer operating.
5. Add remainder of aggregate.
6. Mix until lump free, but less than five minutes.
7. Batch, place, and finish.

Patching material may be batched from a calibrated mobile type mixer or hand mixer. The patch area shall be pre-dampened before the patch material is placed.

Finishing and Setting

The concrete patching material shall be consolidated, vibrated, and screeded, and in the final stages of set, troweled to a smooth finish. No texturing will be required. No water shall be used to finish the surface of the patch. Concrete mixtures shall be placed at a maximum 3 1/2 inch slump.

Duracal concrete mixes shall obtain the following minimum set time requirement before opening to traffic:

Temperature	Minimum Set Time
Less than 55 degrees	3 1/2 hours
Over 55 degrees	3 hours

Approved alternate patching materials other than Duracal concrete shall attain a minimum 2500 psi compressive strength before opening to traffic. Concrete test cylinders will not be required for Duracal concrete mixes provided satisfactory results are achieved. Use of alternate patching materials will require casting of test cylinders to establish set times and minimum compressive strengths.

No curing mats or compounds will be required for Duracal concrete. Approved alternate patching materials shall be cured as recommended by the product manufacturer. In the event of an ambient air temperature below 40 degrees, insulating mats shall be placed on the patches during the set period. No patch material shall be placed when the forecast or ambient temperature is 35 degrees or less.

Before opening to traffic, the contractor shall seal all edges of the patch with a rapid setting polymer modified liquid asphalt emulsion such as "Pavon Repair Material" (Company Phone # 816-221-7721) or equal. The sealed edges shall be coated with a light colored sand to prevent tracking and to blend in with the existing deck. There will be no direct payment for furnishing or placing the "Pavon" or sand.

Measurement and Payment

Areas of partial or full depth bridge deck repairs will be measured to the nearest 1/10 square foot for each individual patch. Minor "punch throughs" in the deck (less than one square foot) will not constitute full depth repair.

The accepted quantities of bridge deck repair will be paid for at the contract unit prices for each of the following:

Item 613-99.01	Bridge Deck Repair (Special), Partial Depth	Square Foot
Item 613-99.02	Bridge Deck Repair (Special), Full Depth	Square Foot

Payment will be considered full compensation for all labor, material, and equipment necessary to complete the work.

Reinforcing steel will be measured and paid for in accordance with Section 710 of the Standard Specifications.

Appendix F
Hydro-Demolition

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 face 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 jackhammers 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 G

Other State Specifications

Jackjackhammer Specifications of Other States

Kansas

Dick McReynolds (Dick@DTMRC.WPO.STATE.KS.US)

E-mail Reply July 30, 1999

Section 722.02 of our 1990 standard specs allow jack jackhammers or chipping jackhammers up to the nominal 15 pound class for partial depth repairs. In areas designated as full depth patching, jackhammers up to the nominal 30 pound class may be used to within six inches of the edges of the areas designated on the Plans or by the Engineer. The remaining six-inch edge shall be removed with up to nominal 15 pound jackhammers. Hammers shall be operated at an angle such that no damage to the sound concrete will occur.

E-mail Reply May 9, 2000

In regards to your question about our maintenance forces' policy on use of jackhammers, I checked with HQ Maintenance and got the following reply:

"The maintenance crews in Kansas do not follow the standard specifications for bridge deck repairs. The equipment available for use are 15 lb chipping jackhammers and 30 lb, 60 lb, 90 lb pavement breakers."
Any more questions let me know.
Dick

Arkansas

Keith A. Stephens (KASD212@ahtd.state.ar.us)

E-mail Reply August 2, 1999

Here at the Arkansas State Highway and Transportation Department we use 45lb. jackhammer at not more than 45 degrees from deck.

Garland V. Land (GVLE101@ahtd.state.ar.us)

E-mail Reply May 11, 2000

To answer your question as to what size jackhammer our crews use on bridge deck repair -- we use 90lb. at any angle.
Thanks: Garland Land; AHTD Heavy Br. Maint. Engr.

Tennessee

Wayne Seger (wseger@mail.state.tn.us)

E-mail Reply August 10, 1999

In Tennessee, we really don't use a Special Provision for guidelines regarding deck repairs. It is handled by notes on the plans. Practically all projects involving deck repairs of one type or the other contain the following note listed in the "General Notes" at the front of plans:
"The contractor shall take special care to protect any parts of the structure that are not to be removed specifically. The contractor is not allowed to use a hydraulic ram mounted on a backhoe (commonly called a hoe ram) or other similarly heavy equipment for concrete removal. Pneumatic jackhammers may be used to remove unsound concrete, for full depth of concrete slab removal except over beams, the maximum jackhammer size is 90 pound class. For partial depth of concrete slab removal and any work over beams, the maximum jackhammer size is 60 pound class. Sawing or cutting of the concrete is acceptable so long as any specified projection of existing reinforcing steel is maintained. All devices proposed for concrete demolition shall meet the approval of the engineer."

We then follow this note up with a detail in the plans showing how we want the repair to look. This would include 1" deep saw-cut edges on the full and partial depth areas and the 3/4" space below the top bar of the top mat of reinforcing steel. The note at this location reads:

Remove concrete in all delaminated areas to a depth of 3/4" below the top bar of the top mat of reinforcing steel. All reinforcing steel in the areas of deck repair shall be completely cleaned. Areas of concrete removal shall be designated by personnel from the Bridge Repair Office. During partial depth repairs, should deteriorated concrete be encountered which appears to run full depth in the slab, the engineer may designate these areas to be repaired under full depth repair. Power driven hand tools used for the removal of unsound concrete in partial and full depth repairs are subject to the following restrictions: 1)(Partial depth repairs) pneumatic jackhammers heavier than nominal 60 pound class shall not be used. 2) (Full depth repairs) pneumatic jackhammers heavier than nominal 90 pound class shall not be used. Also all deck repairs over beams will be restricted to 60 pound pneumatic jackhammers. 3) Chipping jackhammers of 15 pound class shall be used to remove concrete from beneath any reinforcing steel.

If you have any questions, please contact Wayne Seger at 615-741-4044 or email: wseger@mail.state.tn.us

Illinois

Dan Brydl? (DBRYDL@FHWA)

E-mail Reply May 11, 2000

Bill, our spec for contractors says to limit jackhammer sizes to 45 pound class and when you get to the level of the reinforcing steel or below they need to use chipping jackhammers of the 15 pound class. The spec also limits the angle of attack to no more than 45 degrees. I suspect if we did a review of actual practice, we wouldn't see much of the 15 pound jackhammers, but I'm just guessing that.

For the maintenance crews, I did a quick survey. Here is what they use:

District 1 - 40 pound jackhammers
District 2 - 45 pound jackhammers and 25 lb. for chipping

District 3 - 60 pound (even for chipping)
District 6 - 60 pound jackhammers for 90% of their work
45 pound jackhammers just bounce off
90 jackhammers for substructure repairs
District 7 - 35 pound (also for chipping)
District 8 - 45 pound
Central Office Day Labor Crews: 45 pounds

We did a process review on this issue several years ago and did find a lot of damage using the big jackhammers. However, maintenance crews need to get in and get out quickly so they tend to use the bigger jackhammers and just try to be careful.

Hope this helps. Dan

Iowa

Wayne A. Sunday (Construction Field Engineer, Office of Construction, Letter dated August 25, 1999 Tele. 515-239-1185)

Letter received August 25, 1999

I received your request for information concerning bridge deck repair and specification requirements pertaining to the size of jackhammers permitted for repair work. I also talked with you on August 16, 1999, to clarify the information that would be most beneficial to you.

I have enclosed a copy of the specification for bridge deck repair. This is Section 2413, "Surfacing and Repair and Overlay of Bridge Floors" from Iowa DOT Standard Specifications for Highway and Bridge Construction. I highlighted the particular articles in this specification addressing floor repairs and type of equipment permitted.

To provide further clarification to the size of jackhammers permitted for Class A and Class B repair as described in Article 2413.05 "Preparation of Surface for Repair and Overlay" I am including the following comments.

1. Class A bridge floor repair consists of primarily of shallow repair from the surface to the top mat of reinforcing steel. Since this repair is typically not more than several inches deep the specifications permit the use of chipping jackhammers not heavier than a nominal 15 pound class.

2. Class B bridge floor repair consists of full depth removal of the floor. In this case initial removal permits jack jackhammers up to 30 pound class except that the final removal at the edge of the Class B repair area must be accomplished with 15 pound chipping jackhammers or hand tools.

The intent in limiting the size of power equipment used for concrete removal is to ensure better control during removal to sound concrete.

I hope this information will be helpful. Feel free to call me if you have any questions.

Standard Specification

2413.03 EQUIPMENT
Equipment used shall be subject to approval of the Engineer and shall comply with the following:

A. Preparation Equipment.
Preparation equipment shall be of the following types:

3. Power Driven Hand Tools.
Power driven hand tools will be permitted with the following restrictions:

a. Jack Hammers heavier than nominal 30 pound class shall not be used.
b. Jack Hammers or mechanical chipping tools shall not be operated at an angle in excess of 45 degrees measured from the surface of the slab.
c. Chipping Hammers heavier than a nominal 15 pound class shall not be used.

4. Hand Tools.
Hand tools such as jackhammers and chisels shall be provided for removal of final particles of unsound concrete or to achieve the required depth.

2413.05 PREPARATION OF SURFACE FOR REPAIR AND OVERLAY.
Concrete shall be removed from each area, designated in the contract documents or by the Engineer, to a depth and in a manner consistent with the classification for that area. Areas as shown in the contract documents are based on the best information available; actual areas will be determined by the Engineer.

A. Class A Bridge Floor Repair.
Concrete may be removed by chipping, shot blasting, hydro blasting, or by a combination of these, except that final clean up, in any case, shall be by use of hand tools. ETC.

B. Class B Bridge Floor Repair.
ETC. Concrete may be removed by chipping or by a combination of scarifying and chipping, except that the final removal at the periphery of Class B repair areas shall be accomplished by 15 pound chipping jackhammers or hand tools. ETC.

Contacted by phone on May 15, 2000

Wayne Sunday is looking into who would be a good contact concerning maintenance practices however most maintenance is contracted out and would have to follow the criteria below. He will call back this week with who I should contact.

Contacted by phone on May 17, 2000

Wayne Sunday called back. He looked into the bridge maintenance operations on bridge decks in Iowa. Bridge maintenance crews adhere to the same specifications for jackhammer sizes and concrete removal requirements as contractors.