Waterless Bridge Joint Cleaning

FINAL REPORT

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16. Abstract

The purpose of this project was to investigate, develop, and demonstrate a "waterless" method of cleaning sealed bridge deck joints. In this application, waterless refers to minimal use of water and reasonable control and collection of associated runoff and debris. The proposed methodology is best suited to a closed expansion joint that is sealed at the bottom with an elastomeric material having a surface gap of reasonable width and depth (2 x 2 inches maximum). The displaced debris is collected by a vacuum system for later disposal. The design and construction of the system is easy to use and portable and must take advantage of off-the-shelf components.

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CHAPTER 1

Introduction

The Pennsylvania Department of Transportation (PennDOT) maintains a network of bridges constructed with concrete decks. These decks are equipped with expansion joints to accommodate significant expansion and contraction of the deck caused by seasonal variations in temperature. During cold winter months the concrete deck contracts and the gap in the expansion joint widens. The subsequent application of salt and grit to enhance friction during winter months results in an accumulation of debris (fouling) in the joint depression. With the onset of spring and higher temperatures, the deck expands significantly, and the debris trapped in the joint creates compressive stresses that can damage the joint and surrounding concrete. To prevent damage, the bridge joints must be cleaned annually to remove the trapped detritus. To keep bridges in a state of good repair, PennDOT maintenance practices currently include cleaning bridge deck expansion joints by flooding the deck with water to flush out the debris. The runoff associated with this practice can result in contamination of streams and the surrounding land.

The objective of this project was to develop a "waterless" method of cleaning bridge deck expansion joints. A preliminary review of existing joint designs identified several types that are not appropriate for mechanical cleaning. For example, open, interlaced-finger expansion joints do not get contaminated in the same manner as a closed expansion joint with an elastomer sealer installed at the bottom and were not included in the scope of this project.

PennDOT contracted the University to assist in developing and demonstrating a method for cleaning bridge deck expansion joints that minimizes water runoff and environmental impact while effectively cleaning the bridge joint. The University developed, fabricated, and demonstrated a working prototype device. In order to control costs and minimize fabrication expense, the prototype system design utilized off-the-shelf parts and equipment wherever possible. The joint cleaning device consisted of a manually pushed, wheeled trolley that is guided by maintenance personnel at walking speed transversely across the bridge deck over the contaminated joint. As the device passes along the joint, the trapped debris is removed by a rotating brush, contained by a surrounding enclosure, and collected by a vacuum system. The device includes a means for easy emptying of the collected debris into an appropriate waste receptacle. The system includes a generator for electrical power and an industrial vacuum. The system does not require connection to a vehicle for operation.

The prototype device demonstrated the concept of mechanically removing the debris from the expansion joint without water using a rotating brush. However, the prototype design failed to effectively vacuum the wet, muddy debris through the three-inch diameter vacuum hose, and the motor overheated when it encountered the elastomeric sealer that contaminated the joint at the demonstration site. Several recommendations for improving the prototype design are included in this report.

Figure 1. Interlaced finger type bridge expansion joint

Figure 2. Sealed bridge expansion joint with contamination

CHAPTER 2

Methodology

PROTOTYPE DESIGN

The research team investigated several local bridges to examine expansion joint types and geometries to ensure that the developed system will be able to address the most common and problematic bridge joint applications. This effort included local site visits for inspection of common bridge joint designs, materials, and the fouling that occurs. The information gained from the site visits was used to define equipment specifications and identify off-the-shelf equipment and hardware capable of performing the individual functions required by the joint cleaning system. This task included a proposed prototype design sketch, system layout, and an overall description of the system functionality. The objective of the prototype design was to develop a device to evaluate the proof-of-concept.

INITIAL PROTOTYPE FABRICATION AND IN-HOUSE TESTING

Based upon PennDOT’s review and approval of the findings of the Task 1 report, the research team purchased the off-the-shelf equipment and hardware to fabricate the prototype device. Parts that were not commercially available were fabricated on site or by local contractors. Individual components were integrated into a working prototype system.

Figures 3 and 4, Generator and industrial wet/dry vacuum

Based on information gathered during the site surveys, a simulated bridge joint was constructed using wood to create an eight-foot long platform with a two-inch wide by two-inch deep channel running down the center. The channel was packed tightly with fines and gravel collected off the street. This material is very similar in composition to the debris that is commonly found contaminating bridge joints. The geometry and materials provided an accurate representation of an actual bridge expansion joint that allowed traffic-free, in-house testing at the Thomas D. Larson Pennsylvania Transportation Institute's full-scale test track.

Figure 5. Simulated bridge expansion joint for on-site testing

The initial prototype device that was developed under this project was based on a pressure washer nozzle that sprayed a fan-shaped jet of high-pressure water into the bridge joint at an adjustable angle. The nozzle was selected to minimize the total water flow while maximizing the pressure of the jet. The objective was to use as little water as possible to minimize the amount of run-off that would have to be recovered. The nozzle was centered inside a small metal housing mounted on wheels that was pushed over the bridge joint by the operator. A high-volume vacuum system was connected to the housing by a 3-inch-diameter flexible hose. High-pressure water supplied by a power washer was controlled by a lever valve mounted on the device handle.

The water spray in the initial prototype device successfully dislodged the debris from the simulated bridge joint but was not efficient at recovering the wet silt that was dislodged onto the surface of the pavement. Several modifications to the housing failed to correct the poor debris recovery and this prototype concept was eventually abandoned. Drawings of the initial prototype device are provided in Appendix B.

Figure 6. First prototype bridge joint cleaning device

SECOND PROTOTYPE DESIGN

Based on the experience gained from working with the first prototype, a second prototype was designed and constructed. The second prototype device was based on a rotating brush that mechanically dislodged the debris and contamination in the bridge joint. This device was truly "waterless." The wheel brush consisted of two 8-inch-diameter brass "bench grinder" brushes mounted in tandem. This configuration provided an effective brush width of approximately 1 inch. Coarse brass bristles were selected to maximize cleaning efficiency while protecting the integrity of the bridge joint seal.

The brush assembly was mounted into a custom-fabricated, wheeled housing that consisted of a steel enclosure with integral vacuum nozzle, handle with control switch, and drive motor. The drive motor assembly consisted of an off-the-shelf 4-inch angle grinder mounted to the side of the device housing. An adapter coupling was fabricated to attach the brush assembly to the grinder shaft.

Figure 7. Second prototype bridge joint cleaning device

The device was operated by aligning the brush over the contaminated bridge joint, activating the motor, and lowering the rotating brush into the expansion joint. As the brush is lowered, it scrapes out the contaminants and directs the dislodged material toward the vacuum nozzle. The vacuum nozzle creates a seal against the pavement to prevent any material from escaping the housing. The debris is sucked into an industrial wet/dry vacuum cleaner. See Figure 8.

In-house testing was conducted on the simulated bridge joint using both damp and dry contaminants. The device was effective at removing and recovering dry and damp debris up to a depth of two inches. Debris was effectively collected from the surface and the joint and sucked up into the vacuum. Drawings of the second prototype device are provided in Appendix B.

Figures 8. Second prototype device, side cover removed

Figures 9. Second prototype device, front view

CHAPTER 3

Field Demonstration

SITE LOCATION

Prototype field testing was conducted on May 25, 2019 at a site selected by PennDOT. The site was located at the eastbound lane on the Route 17 bridge in Millerstown, Pennsylvania. Traffic control and lane closure was provided by PennDOT personnel.

Figure 10. Demonstration site, Route 17 Bridge, Millerstown, PA

The bridge expansion joint located at the test site was clogged with material composed of the typical fines and aggregate and had not been cleaned. A heavy rain the previous night had saturated the material. The joint was further contaminated by an elastomeric sealer that had been applied generously at the joint edges and had leaked into and on top of the debris in the joint. While sealer contamination of the joint may be typical at bridge locations, the heavy sealer contamination that covered the surface of the joint and enclosed the debris material was not observed at the original sites that were investigated during earlier site visits. The elastomeric properties of the sealer were too resilient to be dislodged and fragmented by the rotation brush. The clumps were not effectively removed and were too large to be vacuumed by the nozzle. Our attempts to remove the sealer using the prototype device failed and caused the motor to overheat. Fortunately, the sealer was relatively easy to peel off the surface of the joint, exposing the underlying dirt and debris.

Figure 11. Bridge joint contaminated with sealer and debris

Figure 12. Pieces of sealer that were manually removed from bridge joint

Figure 13. Technician operating device at demonstration site

Figure 14. Bridge expansion joint after cleaning

CHAPTER 4

Findings and Recommendations

This project demonstrated the concept of using off-the-shelf components to develop a prototype waterless bridge expansion joint cleaning device. The device was effective at removing debris with a low moisture content from a bridge joint but was ineffective at removing excess sealer that had spilled into the joint. During field testing, the prototype device was able to dislodge wet debris from the joint but debris with a mud-like consistency quickly clogged the vacuum hose and rendered the device ineffective.

The prototype device was further limited by the power of the motor. The device utilized an off-the-shelf 4-inch angle grinder to spin an 8-inch, rotating wire wheel. The motor overloaded when it encountered large pieces of sealer that contaminated the joint. This contamination was not encountered during in-house testing but is common in the field.

The time available to complete the project was insufficient to allow additional refinement and experimentation.

The following changes in the design of the prototype device are recommended to improve performance: Increase the power of the motor. The 4-inch angle grinder selected for the prototype did not have sufficient power to dislodge and fragment the elastomeric sealer that can sometimes contaminate bridge expansion joints. A larger 8-inch, heavy-duty angle grinder may provide enough power or a different type of motor drive system is recommended.

The rotating brush that was used for the prototype is an off-the-shelf 8-inch, brass wire wheel. While this brush is not optimal, it is readily available and inexpensive. A thorough search did not identify other types of off-the-shelf brushes that were as effective. However, manufacturers can provide custom brush designs that have stiffer, fiberglass bristles that may be more effective in dislodging and fragmenting the contaminating debris. Care must be exercised in selecting a brush that has stiff bristles but is not so abrasive that it will damage the seal at the bottom of the expansion joint.

Debris that was removed from the joint was effectively sucked into the vacuum nozzle but wet debris clogged the 3-inch hose that transferred the material to the industrial vacuum. This problem could be eliminated by attaching a debris hopper to the front of the cleaning device near the nozzle. The vacuum hose would attach to the sealed hopper and create a suction that would draw the dislodged material through the nozzle, directly into the hopper without having to travel through the hose. At the end of a cleaning run, the hopper could be removed and easily emptied.

Appendix A: Equipment List

The following is a list of basic parts and equipment used to construct the second prototype device:

Quantity	Description
1	Toggle switch (momentary SPST, 10 amp)
3	8” nylon wire ties
1	Dewalt 4” angle grinder DWE4011
3	S.S. locking latches
2	8” course brass wire wheels tractor supply SKU #382229999
1	5/8x11x1 grade 8 bolt
4	5/8 grade 8 washers
2	1/2x20 grade 8 nylon lock nuts
7	1/4x20 nylon lock nuts
4	1/4x20x1 stainless steel bolts
3	1/4x20x½ stainless steel bolts
2	5/16x18x1½ bolts
2	5/16 lock washers
2	3/8x16x½ bolts
2	3/8 lock washers
2	32x ¾ S.S. cap screws
2	8-32 S.S. nylon lock nuts
1	5/8x11x1 coupling nut (modified)
2	1/2 set screw collar, climax C-505
2	8” wheels tractor supply SKU #112817499
1	Aluminum enclosure
1	Fabricated housing
1	Fabricated cover
1	Fabricated handle

General Equipment

1	220 VAC 6000-watt generator (Generac GP-6500)
1	Industrial wet/dry vacuum cleaner (Goodway DV-E3)
1	20’ of 3-inch vacuum hose with connectors

Appendix B: Device Sketches

INITIAL PROTOTYPE

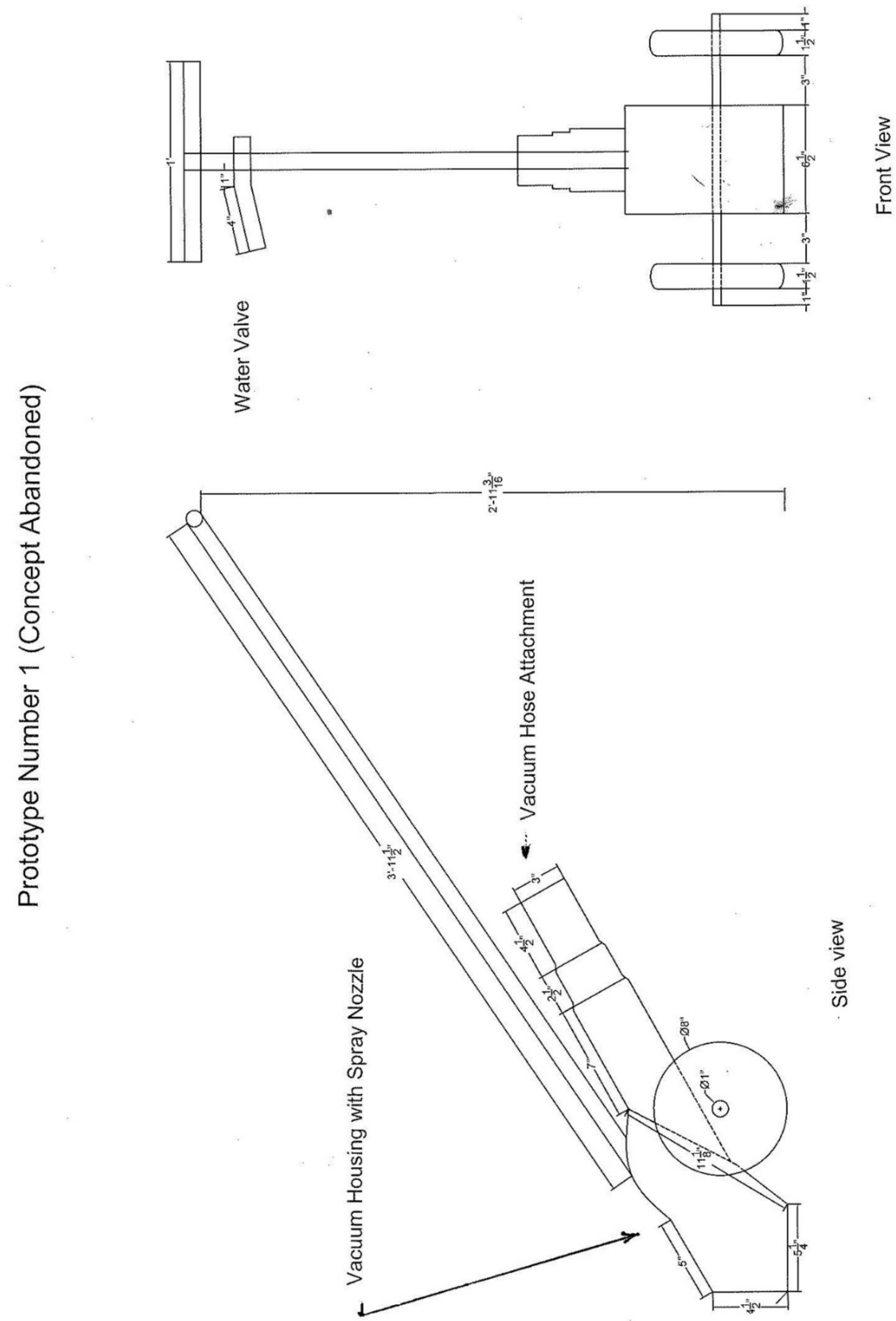

Figure B-1. Initial prototype bridge joint cleaning device

SECOND PROTOTYPE

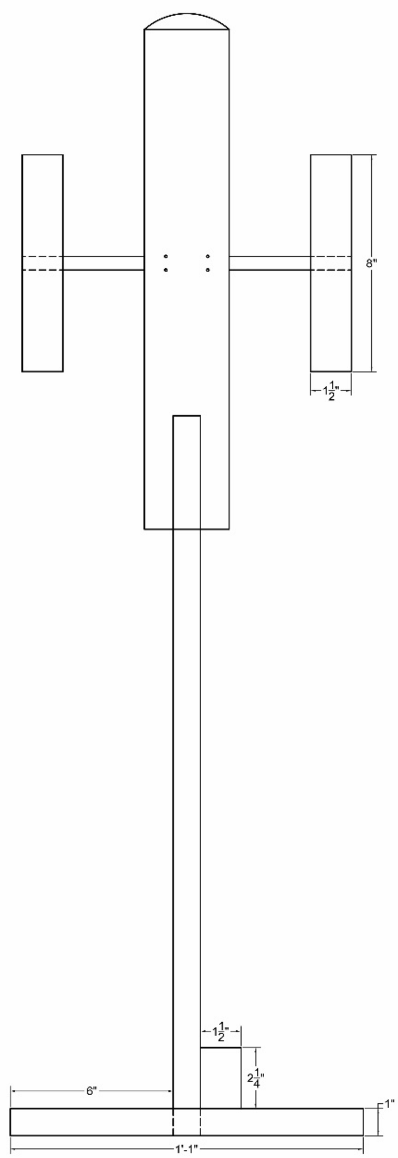

Figure B-2. Second prototype bridge joint cleaning device, top view

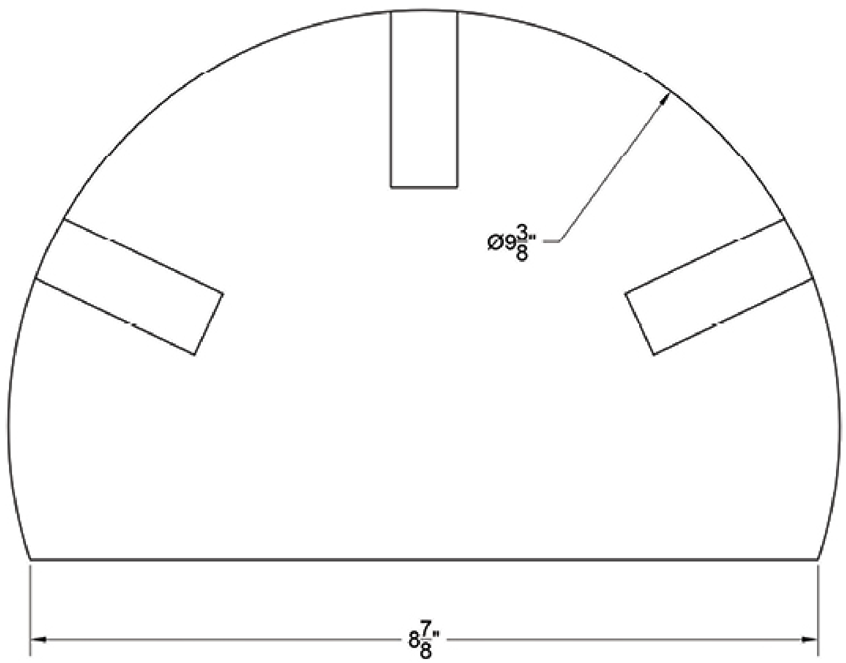

Figure B-3. Second prototype bridge joint cleaning device, right side view

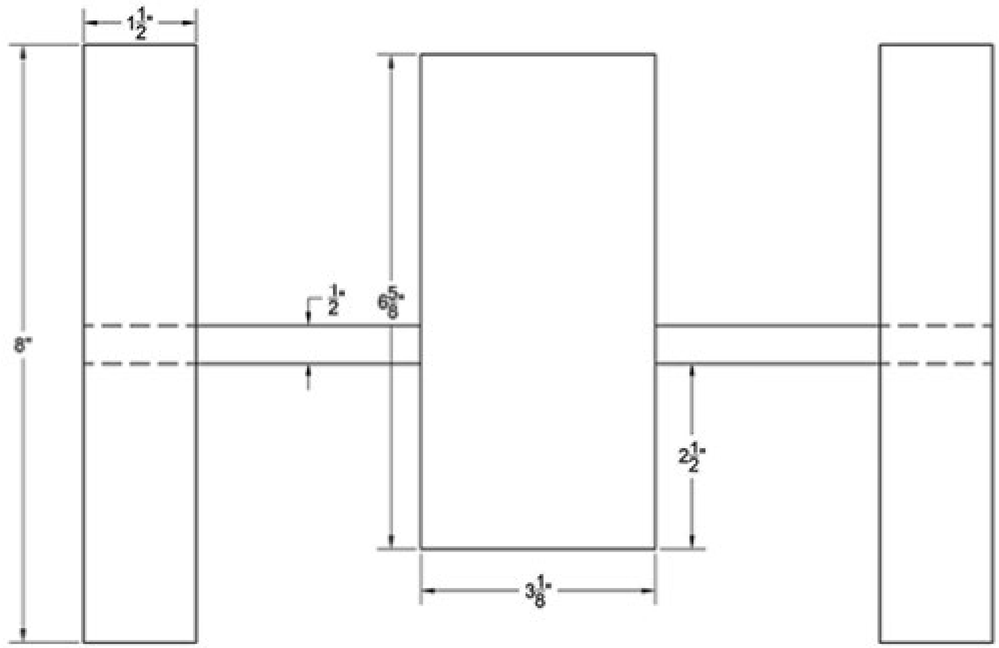

Figure B-4. Second prototype bridge joint cleaning device, rear view

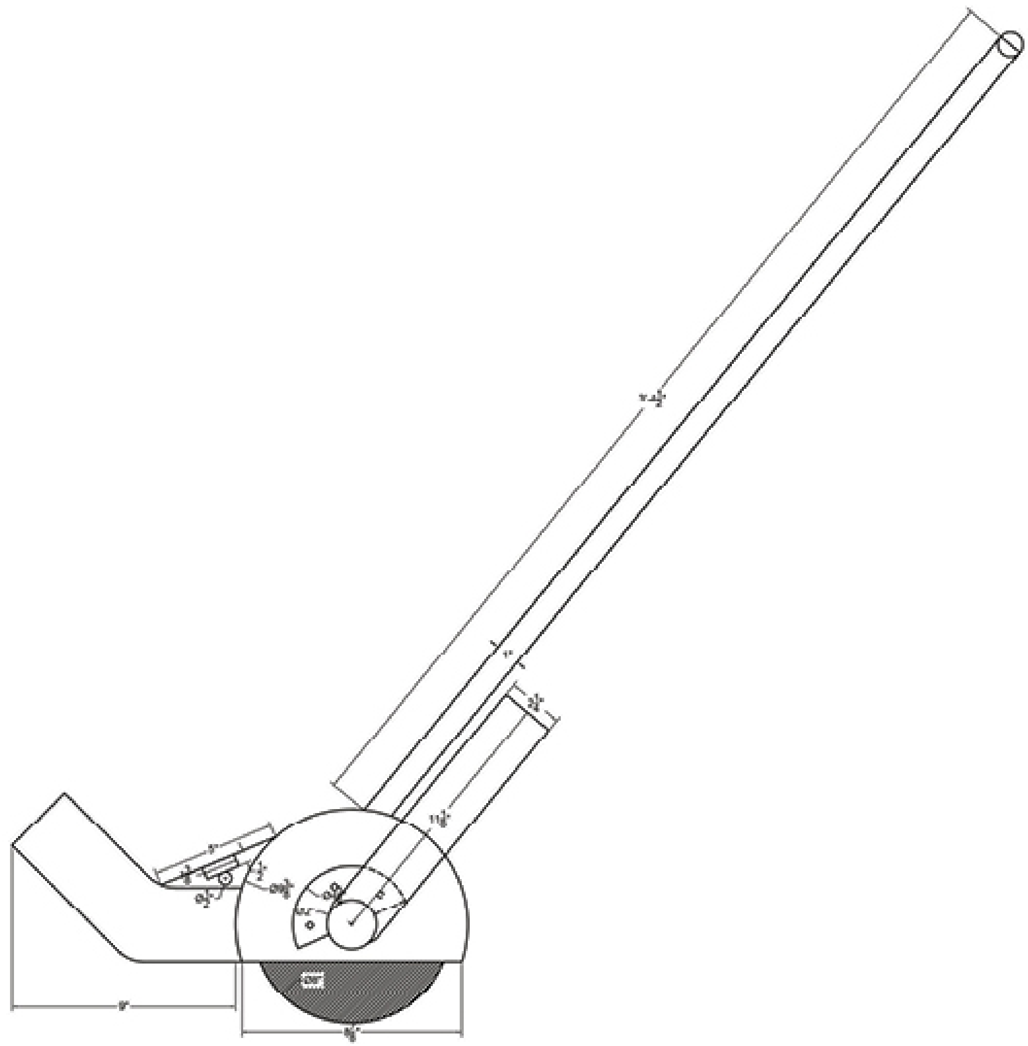

Figure B-5. Second prototype bridge joint cleaning device, left side view