Evaluation of the Method, Cost, And Value of Sealing Systems for Manhole Rings
Failures of the adjusting rings of manholes cost Minnesota cities about $7 million a year in damages to manholes, sewers, and paved surfaces. This study looks at the experience of Minnesota cities and other past research in evaluating the many available methods to repair rings and in recommending construction and repair methods that minimize the risk of damage. Poor construction of manholes and damage from frost heaving cause most failures. When repairs are necessary, survey results suggest three methods with the best cost/value ratios: The Cretex Internal Chimney Seal™, Flex-Seal Utility Sealant™, and Infi-Shield™ seal. One method still under evaluation, rings made of High-Density Polyethylene (HDPE), show some initial indication of success. While lower in initial cost, other methods are less lasting, resulting in a poor cost/value ratio.

Methods also must accommodate the tensile stresses and elongation strains associated with frost heaving through ice lenses. Materials must be elastic enough at sub-freezing temperatures to stretch without breaking when frost heaving opens a joint.
Evaluation of the Method, Cost, and Value of Sealing Systems for Manhole Rings

Final Report
March 2001

Prepared by:
Cameron G. Kruse, PE
Braun Intertec Corporation
6801 Washington Avenue South
Minneapolis, Minnesota 55439

Published by:
Minnesota Local Road Research Board

Printed by:
Minnesota Department of Transportation
Office of Research Services
First Floor
395 John Ireland Boulevard, MS 330
St. Paul, MN 55155

This report represents the results of research conducted by the authors and does not necessarily represent the views or policy of the Minnesota Department of Transportation. This report does not contain a standard or specified technique.
ACKNOWLEDGMENTS

Technical Panel
Larry Read, PE, City of Fairmont, Research Implementation Committee Chair
Richard Petersen, RCM/SEH
John Boynton, PE, Minnesota Department of Transportation
Tom Fournier, City of Mankato
Alan Gray, PE, City of Eden Prairie
Dave Johnson, PE, Minnesota Department of Transportation, Research Operations
Cameron Kruse, PE, Braun Intertec Corporation
Amy Saffel, Braun Intertec Corporation
Ron Tibodeau, City of Windom

Survey Respondents
Braun Intertec would like to thank those people who completed the manhole adjusting ring survey and provided us with valuable information for this report.
Keith Arboledi, City of Mahtomedi
Barron Behning, City of Roseville
Bob Brooks, City of Moorhead
Wess Butts, City of Shakopee
Daniel Chapinski, City of Duluth
Greg Cook, City of Plymouth
Paul Coone, City of New Hope
Rich Cornelius, City of Minneapolis
Jeff Faragher, City of Worthington
John Flora, City of Fridley
Alan Gray, City of Eden Prairie
Byron Hayunga, City of Montevideo
Karl Johnson, City of St. Paul
Don Klint, City of Mankato
Gary Larson, City of Savage
Scott Newberger, City of Plymouth
Larry Read, City of Fairmont
Ron Tibodeau, City of Windom
# TABLE OF CONTENTS

EXECUTIVE SUMMARY i

Chapter 1 INTRODUCTION TO THIS STUDY 1

Chapter 2 WHAT MADE THIS STUDY NECESSARY 3
   Problem Description 3
   $7 Million a Year in Minnesota 4
   Lack of Information Has Limited the Ability to Make Good Repairs 4

Chapter 3 RESEARCH METHODS AND APPROACH 7
   Technical Steering Panel Gave Experienced Advice 7
   Literature Search Found Previous Experience Around the World 7
   Survey of Minnesota Users Tailored the Results to Minnesota 7
   Analyses and Recommendations Make the Information Valuable 8

Chapter 4 RESEARCH RESULTS 9
   Literature Search Fingers Frost Heaving as the Culprit 9
   Survey Results Document Minnesota Experience 10
      Causes of Adjusting Ring Failure 13
      Repair Methods Available 13
      Number of Manholes Repaired and Average Cost of Repair 14
      Cost of Pavement Surface Repairs 14
      Cost of Treatment of Inflow Water 15
      Success of Repair Methods 15
      Cost Per Year of Methods 16
      Changes in Manhole Design or Construction 17

Chapter 5 ANALYSIS 19
   Causes of Adjusting Ring Failures 19
   Best Rehabilitation Methods Available 20

Chapter 6 RECOMMENDATIONS 23
   Appreciate the Need for Good Initial Construction 23
   Current Methods of Rehabilitation 23
   Training 24
   Further Research 24
   Sources for Further Study by Readers 24

REFERENCES 25
LIST OF TABLES

Table 1   Reported Methods of Repair, Costs, and Performance  11
Table 2   Survey Responses for Causes of Failure  13
Table 3   Estimates of Cost and Benefits  16

LIST OF FIGURES

Figure 1.1 Manhole Chimney With Adjusting Rings  1
Figure 2.1 Concrete Adjusting Ring  3
EXECUTIVE SUMMARY

THIS REPORT DISCUSSES RE-SEALING THE CONCRETE ADJUSTING RINGS OF MANHOLE CHIMNEYS

The objective of this research was to document, for use by busy engineers and maintenance superintendents, the best methods of sealing concrete manhole rings used to adjust the height of the top of manholes and catch basins. The report identifies both existing and new methods, documents what works and doesn’t work in Minnesota, and discusses costs and benefits (value). Throughout this report the reference to manholes should be interpreted to include catch basins which have adjusting rings.

$7 MILLION ANNUALLY

This is a $7 million problem annually in Minnesota. From the results of the survey of Minnesota cities it can be extrapolated that there are approximately 600,000 manholes and 200,000 catch basins with concrete adjusting rings throughout the state. Extrapolating the reported number of manholes repaired each year by the reported average cost of repairing a manhole suggests that approximately $4 million is spent each year on manhole and catch basin repairs. Also, the cities reported they do not come close to repairing all the manholes that have damage.

Additionally, there are significant costs associated with pavement surface repairs, treatment of inflow water at sewage treatment plants, and from inconvenience and vehicle expenses for roadway users. State-wide pavement repair costs were extrapolated from the survey information to be on the order of $2 million. Water treatment costs are harder to extrapolate, but it is likely they are on the order of $1 million. We did not attempt to extrapolate users’ costs. However, it appears that total costs from failure of the system of concrete adjusting rings for manholes are on the order of $7 million per year in Minnesota.
THE ENEMY IS FROST (AND POOR CONSTRUCTION)
Manholes and catch basins using concrete adjusting rings to construct the “chimney” are subject to deterioration after installation due to subsequent construction forces, frost heaving, and traffic loads and vibrations. Frost action is likely the primary cause of damage, accelerated by poor initial construction in many cases. Deterioration results in water, soils and manhole pieces entering the manholes, resulting in extra costs of operation for the utility system.

PAY ATTENTION TO INITIAL CONSTRUCTION
Future problems can be minimized by requiring good design and construction practices, including carefully inspecting manhole rings as they are placed and again after paving is complete. Designs allowing a maximum of three adjusting rings seem to be most successful. Inspect the construction to verify the number of rings and that they were properly installed. Inspect again after the paving is complete to check for possible damage due to construction.

THREE “GOOD PERFORMERS” WERE REPORTED
The survey found 2 internal sealing methods and 1 external sealing method that cities generally reported as performing satisfactorily. The internal methods are Cretex Internal Chimney Seal™ and Flex-Seal Utility Sealant™. They can be used without excavating the soils around the manhole. The external method is Infi-Shield™ seal. The initial cost of repair with these methods is higher than some other methods. However, the long-term cost per year of service is significantly less. The time for payback of the cost of this methods compared to other methods is on the order of 1 to 3 years, without considering the costs of treatment of in-flow water or costs incurred by roadway users.

Replacing the frost susceptible soils with clean granular soils around the manhole will greatly minimize the damage to the adjusting rings and any type of repair. However, this creates a problem with the surface since the area around the manhole does not heave in the winter while the area outside the treatment does. Cracking of the surface generally occurs. Tapering the depth of soil replacement smoothes out the transition and minimizes this type of damage.
COST/BENEFIT DOCUMENTATION
The cost/benefit evaluation was limited by the information returned in the survey. The researchers then estimated some cost and life information. With the information available it was estimated that the cost of repairing manhole rings with the Cretex Internal Chimney Seal™ was on the order of $25 per year of life, or less. Flex-Seal Utility Sealant™ and Infi-Shield™ seal have not been in use in Minnesota long enough to document their cost per year of life, but it appears the cost per year of life will be on the order of $15 per year, or less. Other methods ranged from $60 per year to $150 per year. The estimated length of life is the key to a favorable cost/benefit ratio.

HDPE RINGS MAY BE A GOOD REPAIR
We recommend that cities currently using High Density Polyethylene (HDPE) rings closely evaluate them. The performance of the rings should be documented by the cities and the information made available to others. It has been documented that HDPE rings are easier to use.

TRAINING PAYS
Because poor construction was reported as a major cause of the problems, proper construction and inspection training will be very cost effective over the life of the manhole and pavement. Also, when repairs are made the staff should be well versed in the proper analysis of the problem and the correct construction of the repair.

CONSIDER FROST HEAVING WHEN EVALUATING OTHER METHODS
As new methods become available, or are proposed by vendors, they should be studied for their effectiveness. We recommend they be evaluated in terms of their ability to withstand the tensile forces and localized elongation imposed by freeze-thaw action and frost heaving from ice lenses. The sealing system and the materials used must retain their adhesive strength and elastic qualities in sub-freezing temperatures. The materials must have the elasticity for localized stretching as the joints are forced open by frost heaving.

The results of the studies should be made available to agencies’ staffs concerned with the problem. This report will be referenced on the Minnesota Local Road Research Board web site
at http://www.lrrb.gen.mn.us. The Minnesota community would be well served by a web-based technical assistance and discussing forum for issues such as this.

**IF YOU WANT TO KNOW MORE**

The American Society of Civil Engineers has published a manual on manhole inspection and rehabilitation (8) which includes a general discussion of a program to evaluate the performance of an underground utility and identify problems. The manual does not have specific recommendations for methods of repair. See the Annotated References at the end of this report for other sources of information.
CHAPTER 1
INTRODUCTION TO THIS STUDY

The objective of this research was to document, for use by busy engineers and maintenance superintendents, the best methods of sealing concrete manhole rings used to adjust the height of the top of manholes and catch basins. The report identifies both common and new methods, documents current usage and performance in Minnesota, and discusses costs and benefits (value). Throughout this report the reference to manholes should be interpreted to include catch basins, which have adjusting rings.

The primary users of this research will be engineers and maintenance superintendents of cities and other governmental agencies responsible for utility manholes and the surfaces around them. Secondary users are city councils, taxpayers and the traveling public.

Application of the information provided in this report should result in a reduction of the costs of maintenance of manholes, focusing on the methods of sealing existing manhole rings. It should reduce the secondary costs relating to failure of manhole rings - pavement repairs, sewer cleaning, increased wastewater treatment, and travelers' costs. The information from this study should make selection of repair methods easier for engineers and maintenance superintendents and provide documentation to justify their decisions.

The following methodology was used to accomplish the objectives. We

- clarified the problem with an advisory panel of practicing engineers and maintenance superintendents;
- researched literature, Internet sources, anecdotal experiences of the panel, and sales literature from companies providing repair methods or materials;
surveyed selected cities throughout Minnesota to evaluate the methods being used, cost and benefits of the methods, and the size of the problem;

analyzed the information and submitted a draft report of findings and recommendations to the advisory panel for review and comments; and

published the final report of the findings and recommendations.

This study is limited to manholes with concrete adjusting rings as part of the chimney. Other methods of constructing manholes, such as brick and mortar or poured concrete chimneys, were not specifically investigated. This work did not include basic research to create new methods for sealing manholes.

The remainder of this report includes details of the background and scope of the problem, a description of the research methods used, results of the information gathered, and our analysis and recommendations. We have also included recommendations for future evaluations of new methods and a list of additional sources of information the reader may wish to consult for a broader understanding of this and related issues.
CHAPTER 2
WHAT MADE THIS STUDY NECESSARY?

PROBLEM DESCRIPTION
Manholes and catch basins using concrete adjusting rings to construct the “chimney” fail too often. They are subject to deterioration after installation due to subsequent construction forces, frost heaving, and traffic loads and vibrations. Frost action is likely the primary cause of damage, accelerated by poor initial construction in many cases. Deterioration results in water, soils and manhole pieces entering the manholes, resulting in extra costs of operation for the utility system.

When the rings are damaged, such that there are openings between the rings, water enters the manhole from the soils around the manhole. The water may come from a natural water table that is normally at the level of the rings, but most likely is a result of surface runoff that has entered the soils around the manhole through the pavement and aggregate base. This is aggravated when there is settlement around the manhole to concentrate the water collection.

Water entering the manholes creates additional costs. The infiltration/inflow water becomes a costly problem when it has to be treated at a water treatment plant. Water entering the manhole also washes soil in. This results in settlement of the surface around the manhole. The settlement creates a rough surface for traffic and the need for costly pavement surface repairs. The soil in the manhole increases the need for cleaning the manhole and pipelines of the sewer system.
$7 MILLION A YEAR IN MINNESOTA

Repairs associated with the failure of the concrete adjusting ring system cost an estimated $7 million a year in Minnesota. From the results of the survey of Minnesota cities it can be extrapolated that there are approximately 600,000 manholes and 200,000 catch basins with concrete adjusting rings throughout the state. Cities are currently repairing their manholes at an approximate rate of 2 percent of their manholes per year, at an average cost of approximately $250 per manhole. This suggests that approximately $4 million is spent yearly on manhole and catch basin repairs. Also, the cities reported that manholes need repair within 2 to 10 years of initial construction or last repair, such that the 2 percent rate of repair does not come close to repairing all the manholes that have damage.

Additionally, there are significant costs associated with pavement surface repairs, treatment of inflow water at sewage treatment plants, and from inconvenience and vehicle expenses for users. State-wide pavement repair costs were extrapolated from the survey information to be on the order of $2 million. Water treatment costs are harder to extrapolate, but it is likely they are on the order of $1 million. We did not attempt to extrapolate users' costs. However, total costs from failure of concrete manhole rings are on the order of $7 million per year in Minnesota.

LACK OF INFORMATION HAS LIMITED THE ABILITY TO MAKE GOOD REPAIRS

Limited resources at cities, or other agencies, restrict the amount of study each agency can do to minimize their problem. It is difficult enough to find time and resources just to identify the problem manholes. There is a need for a summary of available methods and recommendations for the best methods of repair to allow decision makers to use their resources in the best way. Such a summary did not exist. The major amount of information available is from manufacturers of products. Decision makers are looking for other sources and a summary with recommendations.
Information on the best methods of repair has been lacking so that engineers or maintenance superintendents responsible for repairs have not been able to find good information on which to base decisions. There are only limited studies of the problem and they have not been well publicized. A limited number of articles in magazines report the efforts of some cities to find solutions. The specific issue of sealing manhole rings has not been adequately addressed by professional organizations such as the American Society of Civil Engineers or American Public Works Association. Manufacturers who have materials or products intended to address the issue have sales literature to support their claims of suitable service \{6,7,8,9,10\}. However, most decision makers are not comfortable relying totally on those materials. Information on costs, benefits and the expected life of repairs is generally not available.
CHAPTER 3
RESEARCH METHODS AND APPROACH

This research was divided into four tasks to acquire available information, analyze it, form recommendations and publicize the findings.

TECHNICAL STEERING PANEL GAVE EXPERIENCED ADVICE
The technical steering panel made valuable contributions to this research. The initial task was a meeting with the technical steering panel to clarify the problem and improve the proposed method of research. The panel included representatives of several cities, counties, and Mn/DOT (see the Acknowledgments for a list of members). The panel clarified the problems they were experiencing, expressed the expected outcome of the study, and improved the questions to be asked in the survey of representative agencies.

LITERATURE SEARCH FOUND PREVIOUS EXPERIENCE FROM AROUND THE WORLD
A literature search was completed to find available studies of the issues. This included a search of the Mn/DOT library, computerized data bases of international studies, and a search of information available on the Internet. The cities of Minneapolis and St. Paul and the Metropolitan Council, Environmental Services Division, were contacted to determine if they had unpublished studies of their systems. Manufacturers or distributors of known repair products were contacted. Other personal contacts were made based on panel members’ knowledge of people who were concerned about the problems.

SURVEY OF MINNESOTA USERS TAILORED THE RESULTS TO MINNESOTA
The most valuable information came from a survey of representative cities to determine their experiences with problems, types of repairs, costs and results of those repairs. Responding cities
are noted in the Acknowledgments section. Initially, a written survey was sent to 16 people in cities and consulting engineering companies. Twelve responses were received. The researchers reviewed details of the survey responses and a number of phone contacts were made to get additional details about survey answers. Later, 6 additional cities were surveyed by phone to expand the sample size of the survey. The results of the survey have been summarized and are included in the following section.

ANALYSES AND RECOMMENDATIONS MAKE THE INFORMATION VALUABLE

The data accumulated from the literature search, personal contacts and the survey were then evaluated to draw conclusions about the most effective methods of repair, likely costs, and likely benefits. The technical panel reviewed the draft of the report. Their comments were incorporated into the final report. However, it should be pointed out that the opinions and recommendations included in this report are those of the researchers.
CHAPTER 4
RESEARCH RESULTS

LITERATURE SEARCH FINGERS FROST HEAVING AS THE CULPRIT

Failures of manhole rings due to frost heaving have been recognized in the literature for many years. However, there have been only limited published studies to document the causes and effects. Frost heaving requires a “frost-susceptible” soil, moisture in the soil, and freezing temperatures (no lack of freezing temperatures in Minnesota). Areas with free-draining sands generally do not have a problem with frost damage. Frozen soils adhere to the outside of the concrete rings (or any materials placed around the outside of the rings). Then frost heaving lifts the manhole rings, breaking the mortar joints and separating the rings vertically. As the soil thaws, soil gets into the open joint preventing the joint from closing tightly. Each year the problem increases. \{2\}

Many methods for preventing heaving of the rings have been tried, without significant success. \{2,3,4\} These methods include encasing the rings with various materials or combination of materials, including mass concrete and polyethylene film. Other repair methods which were intended to prevent future problems but have not been successful, include grouting the soils around the outside of the manhole with chemical or cementitious grouts or lining the inside of the manhole with epoxy-based or cementitious layers such as “gunnite.” \{3,4\}

Articles describing studies of manhole failures identify construction activities subsequent to manhole construction as another cause of failures. There is ample opportunity for construction equipment to bump or otherwise impact the manhole after the rings are installed. Thus, inspection of the manholes during construction and after the final surface is in place around the manhole has been noted as important to the proper performance of manhole rings. \{1\}
It is commonly assumed that traffic loads damage rings. No published studies were found to document this source of failure. For damage to occur where the pavement surface is uniform with the top of the manhole it is likely that these rings are either not structurally sound or not correctly installed. However, vibratory effects of traffic loads could, over a period of time, create fatigue failure of the mortar joints between the rings. If the pavement surface settles below the top of the manhole, due to consolidation of the backfill around the manhole or due to soil washing into the manhole through earlier damage, the impact of traffic loads would be significant and could cause failures.

It is also easy to visualize damage due to the impact of snowplow blades on the manhole casting where the pavement surface is not level with the top of the manhole. This source of failure is not specifically documented in the literature.

SURVEY RESULTS DOCUMENT MINNESOTA EXPERIENCE

The following table, Table 1. Reported Methods of Repair, Costs and Performance, summarizes the types of methods used, estimated or documented costs, and perceived advantages and disadvantages, as reported in the survey of 18 Minnesota cities.
<table>
<thead>
<tr>
<th>Method of Repair</th>
<th>Reporting Users</th>
<th>Performance Comments</th>
<th>Range of Total Cost to Install</th>
<th>Average Total Cost to Install</th>
<th>Range of Labor to Install</th>
<th>Average Labor Cost to Install</th>
<th>Range of Material Cost to Install</th>
<th>Average Material Cost to Install</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cretex Internal Chimney Seal™</td>
<td>Duluth, Plymouth, Worthington, Moorhead, Mankato, Fairmont</td>
<td>Performed well. Excellent performance. Installation without excavation. Easy to use but expensive.</td>
<td>$200</td>
<td>$250</td>
<td>$25</td>
<td>$40</td>
<td>$175</td>
<td>$200</td>
</tr>
<tr>
<td>HDPE Plastic Rings</td>
<td>Duluth, Montevideo, Plymouth, Worthington, Eden Prairie, Minneapolis</td>
<td>In process of being evaluated. Trying them now. Seems to work. Performing well. Trying maximum 3 rings per manhole. Wrap with geotextile. Replace frost susceptible soils with sand.</td>
<td>$275</td>
<td>$50</td>
<td>$225</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infi-Shield (Internal Seal)</td>
<td>Worthington, Fairmont</td>
<td>Product fell off after 1 winter.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infi-Shield™ (External Seal)</td>
<td>Roseville, Shoreview, Mahtomedi, Plymouth, Fridley</td>
<td>Using around the rings for last 5 years, mainly on catch basins at curb line. New projects-lay rings on top of one another, no grout, put rubber boot on outside, place 3&quot; sand and 6&quot; base around. Used about 4 years. Used in reconstruction for about 4 years, with 4&quot; of frost-free material in street. Used 1 to 2 years in new roads without frost-free material. Using in marshes with high water table, outside of streets. Been in 2-3 years. Seems OK. Like to use on rebuilds and isolated repairs, with granular around to provide drainage.</td>
<td>$125*</td>
<td>$10*</td>
<td>$115*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3M™ Scotch-Seal Chemical Grout</td>
<td>Plymouth, Mankato, Duluth</td>
<td>Poor results. Early failure rate.</td>
<td>$125</td>
<td>$50</td>
<td>$75</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Method of Repair</td>
<td>Reporting Users</td>
<td>Performance Comments</td>
<td>Range of Total Cost to Install</td>
<td>Average Total Cost to Install</td>
<td>Range of Labor to Install</td>
<td>Average Labor Cost to Install</td>
<td>Range of Material Cost to Install</td>
<td>Average Material Cost to Install</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-----------------</td>
<td>----------------------------------------------------------------------------------------</td>
<td>-------------------------------</td>
<td>-------------------------------</td>
<td>----------------------------</td>
<td>-------------------------------</td>
<td>----------------------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>Flex-Seal Utility Seal™</td>
<td>Fridley</td>
<td>Seems to work. Used with a few catch basins. Works, but too spendy. Used 1 year, looks good.</td>
<td>$125</td>
<td>$50</td>
<td>$75</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Plymouth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Savage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrapid Seal™</td>
<td>Plymouth</td>
<td>Not enough time or experience to know if it works.</td>
<td>$600</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anchor System</td>
<td>Worthington</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Plug™</td>
<td>Duluth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Encapsulate Rings with Concrete</td>
<td>Duluth</td>
<td>Form with pipe or C-form Seems to work. Expensive. Tough to remove.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mahtomedi</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-shrink Grouts</td>
<td>Duluth</td>
<td>Use only non-shrink grout for rings. Use only for “quick fix.”</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moorhead</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brick and Mortar</td>
<td>St. Paul</td>
<td>Use only brick and mortar for repairs. Very happy with results. Considering banning adjusting rings.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Cost information is for manhole repair only. Pavement surface repairs are not included.
CAUSES OF ADJUSTING RING FAILURE
The most common cause for adjusting ring failure given by the respondents was poor construction methods. This included improper grouting between rings, poor compaction of the material surrounding the manhole, and exceeding the allowable number of rings. Also cited as common causes were traffic loading and moisture. The responses are tabulated in the following table.

Table 2. Written Survey Responses for Causes of Failure.

<table>
<thead>
<tr>
<th>Reported Cause</th>
<th>Number of Responses</th>
<th>Percent of Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor Construction Methods</td>
<td>8</td>
<td>36</td>
</tr>
<tr>
<td>Moisture</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>Traffic Loading</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>Freeze-Thaw Cycle</td>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>Poor Soils</td>
<td>3</td>
<td>14</td>
</tr>
</tbody>
</table>

REPAIR METHODS AVAILABLE
There are various types of methods available for repairing damaged rings. They include mechanical seals, internal and external grouting, encapsulation of the manhole, and reconstruction.

The survey of Minnesota cities found several methods that were in common use or had been tried by a number of cities. The most common include:

- Cretex Internal Chimney Seal™, an internal seal
- High Density Polyethylene Rings (HDPE), for reconstruction,
- Infi-Shield™ seals, an external seal,
- 3M™ Scotch-Seal Chemical Grout 5610 (Gel) for external grouting, and
- Flex-Seal Utility Sealant™ by Sealing Systems, Inc., an internal seal.
Other systems reported in the survey or in the literature include:

- PERMACAST© Mortar, an internal grout seal,
- Wrapid Seal™,
- Anchor System,
- Non-shrink grout, repair of the mortar,
- Water Plug, repair of the mortar,
- Inliner by Inliner Technologies, Inc, an internal seal,
- NPC Manhole Joint Seals, by PrimeLine Products, Inc., and
- Manhole Riser, by American Highway Products, Ltd.

There are likely other products available which are similar to the ones noted above.

**NUMBER OF MANHOLES REPAIRED AND AVERAGE COST OF REPAIR**

In the last 5 years the reporting cities repaired between 0 and 500 manholes per year. This was highly dependent on the size of the city. Repair cost per manhole ranged from $125 to $1200, depending on the type of repair used and the number of manholes per year. It appears that the average cost per manhole was about $250.

On average, the cost to repair was about evenly split between materials and labor. Some cities reported nearly 90 percent labor for their selected repair. Others indicated a materials cost of approximately 67 percent for other repair methods.

**COST OF PAVEMENT SURFACE REPAIRS**

The majority of the survey respondents indicated that the roads in need of manhole repairs were at least 20 years of age. Many noted that the age varied greatly, with some as low as 1 to 2 years. Since repairs are related to failure of the manhole rather than failure of the pavement, pavement age is not thought to be a good indicator of the need for or cost of repairs.
The cost of the pavement surface repairs was highly dependent on the method of repair. A cost of $30 per repair was reported for a “throw and roll” (cold patch) method. However, most repairs involved cutting out a section of pavement, replacing the sub-base and base with compaction and then re-paving. This method had estimated costs of $200 to $500, generally around $250.

**COST OF TREATMENT OF INFLOW WATER**

The cost to treat water that enters the manhole through the failed rings has not been studied much by the cities responding to the survey. Survey responses estimated as much as $200 per manhole per year in areas of high water table. Literature studies of areas where inflow was known to be significant identified costs on the order of $500 per manhole per year.

The published studies found that most inflow comes from surface water entering the aggregate base of the pavement. A high water table was not required. Thus, inflow costs in Minnesota may be underestimated.

**SUCCESS OF REPAIR METHODS**

The survey found three methods that several Minnesota cities felt are working successfully. The Cretex Internal Chimney Seal™ has been in use for over 10 years with consistent reports of success. Infi-Shield™ has been in use over 5 years satisfactorily. Flex-Seal Utility Sealant™ has been in use over 2 years satisfactorily. The use of HDPE rings is thought by some to be successful, but others feel it is too soon to tell. The city of St. Paul is very happy with the process of replacing rings with brick and mortar. Other methods had variable or no successful applications.

It appears that the successful methods must be able to stretch and recover to accommodate the opening of the joints between the rings caused by frost heaving. For long-term success, internal methods may have to be able to accommodate cumulative movement over many winters since research has indicated that soil gets between the rings as thawing occurs,
holding the joints open more each year. It should be noted that maintaining a watertight seal should minimize the soil movement into the joints.

**COST PER YEAR OF METHODS**

The cost information from the survey was quite limited. It has been supplemented with researchers’ estimates of other costs to allow a rough comparison among methods.

The cost benefits of each method were not defined in the survey. For purposes of this evaluation the only benefit considered was the reported or estimated “life” of the repair. There are other benefits, such as public attitude about the performance of the pavements they drive on and the frustration level of the people who are responsible for manhole repairs.

The following table presents the estimates of the cost per year of the various methods. It should be noted again that these ratios are only approximate and they are relative to the assumptions about average life of the repairs.

**Table 3. Estimates of Cost and Benefits**

<table>
<thead>
<tr>
<th>Repair Method</th>
<th>Average Cost per Manhole Repaired</th>
<th>Average Life of Repair</th>
<th>Cost Per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cretex Internal Chimney Seal™</td>
<td>$250</td>
<td>10+ years</td>
<td>≤$25/year</td>
</tr>
<tr>
<td>HDPE plastic Rings</td>
<td>$250</td>
<td>not determined</td>
<td>not determined</td>
</tr>
<tr>
<td>Infi-Shield™ (External Seal)</td>
<td>$125</td>
<td>5+ years</td>
<td>≤$25/year</td>
</tr>
<tr>
<td>3M™ Scotch-Seal Chemical Grout</td>
<td>$125</td>
<td>2 years</td>
<td>$63/year</td>
</tr>
<tr>
<td>Flex-Seal Utility Sealant™</td>
<td>$225</td>
<td>2+ years</td>
<td>≤$125/year</td>
</tr>
<tr>
<td>Wrapid Seal™</td>
<td>$600</td>
<td>not determined</td>
<td>not determined</td>
</tr>
<tr>
<td>Anchor System</td>
<td>$300</td>
<td>2 years</td>
<td>$150/year</td>
</tr>
<tr>
<td>Water Plug</td>
<td>$100</td>
<td>1 year</td>
<td>$100/year</td>
</tr>
<tr>
<td>Encapsulate Rings with Concrete</td>
<td>$300</td>
<td>not determined</td>
<td>not determined</td>
</tr>
<tr>
<td>Repair Method</td>
<td>Average Cost per Manhole Repaired</td>
<td>Average Life of Repair</td>
<td>Cost Per Year</td>
</tr>
<tr>
<td>--------------------</td>
<td>----------------------------------</td>
<td>------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Non-shrink Grouts</td>
<td>$300</td>
<td>2 years</td>
<td>$150/year</td>
</tr>
<tr>
<td>Brick and Mortar</td>
<td>$200</td>
<td>not determined</td>
<td>not determined</td>
</tr>
</tbody>
</table>

**CHANGES IN MANHOLE DESIGN OR CONSTRUCTION**

Several cities reported recently revising their plans and specifications for manhole construction. Generally, the revisions reduced the use of concrete adjusting rings. Three cities limited the number of rings that could be used, with limits ranging from 2 to 6. One city said it was considering eliminating the use of adjusting rings. Several cities are experimenting with HDPE rings in lieu of concrete rings. Several cities are placing clean granular soils around the manholes to limit frost damage.
CHAPTER 5
ANALYSIS

CAUSES OF ADJUSTING RING FAILURES

The primary causes of adjusting ring failures appear to be poor construction and damage due to freeze-thaw cycles. It is likely that poorly constructed manholes will suffer deterioration, made worse by freeze-thaw action and traffic loads. Freeze-thaw forces of frost susceptible soils will also damage the rings, and the mortar joints between them, in well-constructed manholes. Freeze-thaw forces will also damage most repair methods.

The survey responses for causes of adjusting ring damage differ from the causes reported in research literature. Minnesota cities identified poor construction more than frost heaving. The literature indicated the freeze-thaw cycle to be the biggest cause of damage. Perhaps the published research assumed good construction. Perhaps the survey respondents felt that with better construction the freeze-thaw cycle would not have a negative effect.

The mortar joints and many of the materials used in repairs are not capable of withstanding the tensile forces and the elongation strain (stretching over short lengths) that occurs when a frost susceptible soil freezes onto the manhole and ice lensing stretches the manhole. The power of ice adhering to the manhole materials and the strain created by the formation of ice lenses is greater than many materials can withstand. Even most geotextiles, or geofabrics, can not withstand the amount of strain imposed by the ice lensing of frost susceptible soils. Often these materials tear and therefore fail to keep the soils from washing into the manhole.
BEST REHABILITATION METHODS AVAILABLE

It appears from the literature and the experience of those responding to the survey that a repair system that can overcome the action of frost heaving will have the best results. The Cretex Internal Chimney Seal™ was consistently reported to be successful in applications that have exceeded 10 years. This method can be installed without digging up the soils around the manhole. This method is more expensive to install than some methods and less expensive than others, but the results indicate the initial cost is justified by the long-term performance of the repair. A newer method, with over 5 years of successful history, is the Infi-Shield™ external seal. This is an external seal, requiring removal of the soil around an existing manhole for installation. (It is a relatively easy installation around a new manhole) Another new method, with about 2 years use in Minnesota, is the Flex-Shield Utility Sealant™. This is an internal sealant so removing soils around an existing manhole is not required.

HDPE rings are easier to construct correctly so they may prove to be advantageous, particularly where frost action is not severe or is eliminated by replacing frost susceptible soils.

Replacing the frost susceptible soils around the manhole with clean sands will eliminate frost heaving as a source of damage, but at considerable cost. The thickness of the replacement sands has to be tapered away from the manhole to avoid an abrupt change in frost heaving of the pavement surface at the edge of the replacement. An abrupt change results in a depression at the manhole as the pavement around it heaves. The pavement may crack at the change. The taper should be a minimum of 4:1 (horizontal:vertical) for low speeds and limited frost heaving, or up to 20:1 for high speeds and severe frost heaving. Constructing a tapered soils replacement increases the cost of this repair.

Other repair methods have only limited success in frost susceptible soils. It seems clear that seals of inflexible materials, such as grout and encapsulation materials, suffer from frost damage and ultimately fail. The failure may take one winter or several, depending on the treatment method and frost conditions. Flexible seals on the outside of the manhole may also fail, likely from being stretched too far in the immediate area of the ice lenses. Any repair which is not able to
accommodate the tensile forces and vertical movements created by ice lenses will not be successful. Internal seals must be able to elongate to accommodate all the movement at the joints between rings to avoid rupturing and failure of the seal.
CHAPTER 6
RECOMMENDATIONS

APPRECIATE THE NEED FOR GOOD INITIAL CONSTRUCTION
Manhole problems can be minimized in the future by requiring good design and construction practices and spending the time to carefully inspect manholes as the rings are placed and after the pavement is complete. Designs allowing a maximum of three adjusting rings seem to be most successful. Inspect the manhole construction to verify the number of rings used and their proper installation. Inspect again when the paving is complete to check for subsequent construction damage.

CURRENT METHODS OF REHABILITATION
The reported method with the longest record of good performance is the Cretex Internal Chimney Seal™. The Infi-Shield™ external seal has about a 5-year record of satisfactory performance, particularly when combined with replacing frost susceptible soils with frost free soils outside the manhole. Flex-Seal Utility Sealant™ has also shown promise of satisfactory long-term performance. If it is not necessary to excavate the soils around the manhole for other reasons, consider the Cretex Internal Chimney Seal™ or the Flex-Seal Utility Sealant™ to seal the manhole. If the soil must be excavated, Infi-Shield™ becomes another option.

The initial cost of repair with these methods is higher than some methods. However, the long-term value greatly exceeds that of other methods. The time for payback of the cost of these methods compared to other methods is on the order of 2 to 3 years, without considering costs of pavement repairs, treatment of in-flow water or user costs.

Replacing the frost susceptible soils with clean granular soils around the manhole will greatly minimize the damage to the adjusting rings and any type of repair. However, this creates a problem with the surface since the treated area around the manhole does not heave in the winter while the area outside the treatment does. The surface generally cracks at the boundary.
Tapering the depth of soil replacement smoothes out the transition and minimizes this type of damage.

We recommend that the use of HDPE rings be closely evaluated by those cities currently using them. The performance of the rings should be documented by the cities and the information made available to others.

TRAINING
As always, training construction staff in the need for good construction and inspectors in the value of good inspection will be very cost effective over the life of the manhole and pavement. Also, when repairs are made the staff should be well versed in the proper analysis of the problem and the correct construction of the repair.

FURTHER RESEARCH
Other methods not reported in the survey may be available, or be proposed by vendors. We recommend the methods be evaluated in terms of their ability to withstand the tensile forces and localized elongation imposed by freeze-thaw action and frost heaving.

The results of the studies should be made available to agencies’ staffs concerned with the problem. This report will be referenced on the Minnesota Local Road Research Board web site at http://www.lrrb.gen.mn.us. The Minnesota transportation community would be well served by a web-based technical assistance and discussion forum for issues such as this.

SOURCES FOR FURTHER STUDY BY READERS
The American Society of Civil Engineers has published a manual on manhole inspection and rehabilitation (8), which includes a general discussion of a program to evaluate the performance of an underground utility and identify problems. The manual does not have specific recommendations for methods of repair.

Various manufacturers have Web pages to describe their products and product availability.
ANNOTATED REFERENCES

   Inliner is a patented method of lining pipes with a needled polyester felt tube impregnated
   with resin after installation in the pipe.

2. "Adjustable Manhole Product Rises to the Occasion," PUBLIC WORKS, September, 1999,
   page 36-38
   Describes an expandable steel manhole riser. Quotes 2 cities' experience. South Bend
   Indiana - population = 115,000; 25 to 30 overlay miles per year; 900 to 1000 utilities
   adjusted per year; 8 different styles of utility castings. Started using in 1996.
   Chattanooga, TN - population = 300,000; 1,200 miles of street; Test installation in 1986.
   Used exclusively since 1991. Average 250 risers per year; "The city saves an average of
   $130 per adjustment... Another advantage is that there are no utility patches in the newly
   paved road."

   Fitting Unplasticized Polyvinyl Chloride Pipeline System Resisting to Ground Subsidence,"
   Paper describes manhole built to avoid breaking pipeline at joint with manhole. Not
   applicable to our study.

5. "Internal Manhole Chimney Seal," Cretex Specialty Products, 5/89
   Sales brochure describing internal rubber sleeve with stainless steel sealing bands. Also,
   suggested specifications for bidding and construction.

6. Kryz, Bernard P., "Manhole Rehab Business is Down the Hole," Trenchless Technology,
   August, 1994
   Article describes a patented system (Permacast©) for installing a centrifugally applied
   cementitious liner with a robotic applicator. Also structurally improves the manhole. No
   report on long-term effectiveness.

7. "Austin’s Program of Manhole Maintenance," PUBLIC WORKS, February, 1999, pages 22 -
   24
   Article describes manhole maintenance in Austin, TX. 40,000 existing manholes. New
   manholes receive a protective coating of epoxy at the time they are installed. Repairs
   start with cleaning and neutralizing the interior surfaces. Leaks and structural failures are
   corrected. Protective coatings (cementitious or epoxy) are applied.

8. Manhole Inspection and Rehabilitation, ASCE Manuals and Reports on Engineering
   Practice No. 92

   Brochure describes a flexible sealant made of aromatic urethane rubber to be installed on the
   inner wall of a manhole, after surface preparation.
10. "Infi-Shield™ External Sealing System," Sealing Systems, Inc. product brochure. Brochure describes a sealing system using continuous bands made of Ethylene Propylene Diene Monomer (EPDM) rubber that are applied around the outside of the manhole.