Utilicor™
TECHNOLOGIES INC.

Utilibond™

Permanent Pavement Bonding Compound

Reference Manual

The cutting edge in keyhole technologies™

Contents

UTILICOR™ Technologies Inc. is the exclusive manufacturer and distributor of the field-proven, keyhole pavement coring and reinstatement system, used by more than 30 major gas utilities and dozens of contractors in the United States, Canada, the United Kingdom and France.

The Utilicor process combines a purpose-built, field-proven Utilicor coring unit with Utilibond™, a proprietary core bonding compound, which has been specifically developed for the permanent reinstatement of cored pavement coupons in all types of paved roads and sidewalks.

Utilicor Technologies Inc. is the world leader in providing the equipment necessary for the proper implementation of the keyhole coring and reinstatement process for natural gas and other utilities and their contractors, and has successfully helped these companies launch and maintain a cost effective keyhole program to address all their small hole needs.

With more than 100,000 reinstated cores in both roadways and sidewalk over the past 20 years, Utilicor is helping the utility industry increase their internal efficiencies, achieve a greater return on their investments, reduce the impact of utility construction practices on the travelling public, and, at the same time, helping utility companies and their contractors worldwide become greener and cleaner while performing necessary utility repairs to their buried underground infrastructure.

The Utilicor coring and reinstatement process has been tested and approved by the National Research Council of Canada, the United States Army Corps of Engineers, and by AASHTO approved laboratories, as well as the materials testing facilities of the Department of Engineering of the University of Illinois.

Utilibond™, our proprietary bonding compound, is an integral part of that reinstatement process and has fast become the industry standard. Independent testing has shown that it creates a bond that is stronger than the original pavement and is capable of supporting the combined weight of six transit buses - more than 50,000 lbs.

Surgeons have recognized for years that, when it comes to making holes, smaller is better. Keyhole surgery is less intrusive and causes less trauma and tissue damage to the patient, which means a shorter recovery period. The smaller incision also heals faster and leaves a smaller scar. It is also costs less because it consumes fewer resources and has less impact on the patient during recovery. The same holds true for cutting holes in roads to access, repair or view buried infrastructure.

With annual pavement excavation and restoration of more than $2 billion annually, gas system operators are turning to keyhole methods as a way to reduce overall maintenance costs. Keyhole methods can cut excavation, repair and restoration costs in half. With keyhole techniques, maintenance activities are done through small pavement openings called "keyholes", which add up to significant cost savings, reduced public inconvenience, and a better, longer lasting repair.

Keyhole technology is a cost-saving alternative to common repair methods, that usually require large "open" excavations and the removal and disposal of large quantities of pavement debris or spoils. Conventional excavation practices that account for over 80% of the total costs of the work, also involve several large pieces of equipment (backhoes, dump trucks, pavement breakers) that generate more than SIX times the amount of CO_2 and other Green House Gases as compared to keyhole methods which are significantly more environmentally friendly.

The process itself is really quite simple. A purpose built piece of coring equipment precisely cuts a circular core, typically 18" in diameter, through the roadway or sidewalk. That core is removed and put aside for future reinstatement. Vacuum excavation equipment is used to dig down to access the buried infrastructure, and the repairs are performed from the surface using long handled tools. Once the work or inspections are finished, the hole is backfilled and compacted to the base of the pavement, and the original core of pavement is put back into the opening using a specially formulated bonding compound – **Utilibond™** - which creates a permanent, waterproof, mechanical joint with the existing roadway.

Thirty minutes later, the road will have regained its pre-excavation load bearing capacity and can once again be safely reopened to traffic. No temporary patches. No sunken potholes. No unsightly scaring of the roadway.

Just a perfectly clean, neat and almost invisible permanent repair to the road.

The benefits from utilizing keyhole technology are almost too numerous to mention - and applications are growing every year. It is a true win-win-win technology. Not only is it better for the community in which it is used, it is a better process for those using it, the crew, and perhaps most importantly for the planet on which we all live. It is a green technology that results in a dramatically smaller carbon footprint when compared to traditional construction techniques. It saves tax payers and utility companies millions of dollars when compared to traditional methods of utility cut repair.

Benefits for the utility company, their contractors, and the municipality:

- **Saves Money:** Dramatically reduces repaving budgets. Saves up to $1,000 per hole or millions of dollars or more per year vs. traditional cut & repair methods.

- **Positive Community Relations:** Faster less intrusive process. Fewer complaints from municipalities about traffic disruption, unsightly road cuts, sunken patches or weakened or failed roads.

- **100% Performance Index:** Field-proven process with **ZERO** reported failures in more than 20 years and over 100,000 successful core reinstatements in tough urban climates.

- **Improved Logistics:** Single crew, one-stop, same-day coring and pavement reinstatement means simplified scheduling, no temporary patching or repaving and no repeat visits.

- **Faster & Efficient:** The speed with which the Utilibond gains strength - 50,000 lbs. in 30 minutes @ 70° F, (can support 5 transit buses) is unique and not seen in other pavement restoration processes. Time is money. Instead of waiting around an hour or more until other products gain sufficient strength to reopen the road, with Utilibond, after just 30 minutes the road can be safely reopened to traffic, allowing the crew to move on to another job.

Benefits for the Crew:

- **Easy to Operate:** No extensive training required to operate the coring unit.

- **Easy on the Back:** Coring and reinstatement is physically less demanding on the crew. It eliminates the need for jack-hammers, shovels and backhoes and reduces potential for workplace injury.

- **Easy to Use:** Utilibond™ permanent pavement repair compound is packaged in easy-carry, easy-open, pre-measured pails. No awkward measuring and mixing from fragile paper bags and no guesswork. Just add water to the line, mix and pour into the hole.

- **Safe:** Work-safe engineered equipment and non-hazardous bonding materials.

- **Reliable:** Utilicor coring units are the only Heavy Duty, purpose-built, coring equipment capable of quickly and accurately cutting through asphalt, asphalt-concrete and reinforced concrete road systems and sidewalks with a minimum of effort.

Benefits for the Community:

- **Reduced Traffic Disruption:** Faster one-step permanent pavement repair means reduced traffic disruption with fewer and shorter road closings and no repeat visits. The road can be reopened to traffic just 30 minutes after the repair.

- **Saves Tax Dollars:** Less intrusive, more precise, pavement coring and reinstatement process means less structural damage to road system, longer pavement life and reduced maintenance. Saves millions of tax dollars.

- **Environmentally Friendly with Reduced Carbon Footprint:** This is a one-stop road closure that uses the same materials to repair the road that were used to build it in the first place. No road-cut spoil needs to be trucked away and disposed of and no temporary patching materials with volatile organic compounds (VOC's) that escape into the atmosphere are used in the process. As a result, keyhole coring and reinstatement emits less than ONE-SIXTH of the amount of green house gases (GHG) than an equivalent repair using conventional methods.

- **Cleaner, Safer, Less Intrusive Worksite:** Neat, almost invisible, 18-inch diameter circular, keyhole core (area: 1.75 sq. ft.) vs. 2 ft. x 4 ft. conventional rectangular road cut (area: 8 sq. ft.) means a perfectly matching repair and reduced 'scarring' of the community landscape. No jackhammers or large excavation equipment means less noise and mess during and after the excavation and reduced disruption for neighbors.

Utilibond™ is the only specially formulated and engineered bonding compound designed to be used to permanently reinstate pavement cores in asphalt and concrete roads, sidewalks and other paved surfaces that has been mandated by D.O.T's for use in some jurisdictions.

Utilibond™ is a multi-component, super-plasticized, cementitious compound specifically engineered and designed for bonding concrete and asphalt cores back into the road or sidewalk.

Unlike typical "grouts" which are moderate strength fillers used for filling cavities, voids and cracks, **Utilibond™** contains special additives designed to enhance the bonding performance of Portland cement-based materials.

This unique blend of components results in high cohesive strength, through high density and low water absorption, and improves the mechanical performance, workability, adhesion and resistance to harsh environmental exposures of the product such as freeze-thaw scaling.

A ready-to-use (just add water), fast-setting, high-strength waterproof bonding agent, **Utilibond™** is non-toxic and comes in two colors **(Aged Asphalt and Natural Concrete)** and has full strength gain in just 30 minutes at 70° F.

FEATURES:

- **Specially Designed for Keyhole Core Reinstatements**
- **Super Strong Bond Strength: 50,000 lbs.**
- **Exceeds AASHTO H-25 and ASTM 928 Standards**
- **Gains full Strength in Just 30 Minutes**
- **Creates a Waterproof Joint**
- **Excellent Freeze-Thaw Resistance**
- **Field-Proven 20 years – ZERO Failures**
- **2 years Shelf Life**

D.O.T. Approved and Tested by:

- **US Army Corps of Engineers**
- **National Research Council of Canada**
- **Dept. Engineering, University of Illinois Urbana Champaign**
- **AASHTO Approved Testing Laboratory**

Colors: Aged Asphalt (UB-AA) is designed to more closely match the color of an asphalt top roadway, and Natural Concrete (UB-NC) is designed to closely match concrete topped roadways or sidewalks.

Sizes: The standard sized pail of Utilibond™ is 44 lbs. with one plastic lined bag of the Utilibond powder packaged in air tight 5-gallon plastic containers. This single use quantity is designed to reinstate an 18" diameter core up to 18" in depth. For shallower or smaller diameter cores, Utilibond™ is also packaged as a **"Twin Pack"**, which has two separate bags of the Utilibond powder, each weighing 22 lbs., which can be mixed separately or together to give the worker the flexibility to use just the right amount of Utilibond according to the depth / diameter of core being reinstated.

Shipping: Utilibond™ comes packaged in skid lots of 48 pails, in either Standard or Twin Pack configuration. Smaller quantities are available as required. Utilibond is shipped through one of Utilicor's authorized distributors, or directly from Utilicor.

Storage: Utilibond has a shelf life of at least 2 years from the date of manufacture. Utilibond should be stored out of direct sunlight as ultraviolet rays can deteriorate the plastic pails. Storage can be either inside or outside. Freezing temperatures do not affect Utilibond.

The coring and reinstatement process was developed and field proven in the **City of Toronto**, where it was ultimately accepted and approved as a permanent pavement repair after monitoring the performance of thousands of reinstated cores in city streets from 1988 to 2003. To date, more than 100,000 cores have been cut and reinstated in North America, with zero reported failures.

As part of the proof, **Golder Associates**, an internationally respected science and engineering firm was retained to monitor the development of the pavement coring and reinstatement process and to evaluate a broad range of potential bonding products. Among the evaluation criteria for the selection of the appropriate bonding material were:

- fast setting and rapid strength gain to minimise traffic disruption
- high bond strength to exceed AASHTO standards (safety factor) and to create a long-lasting, mechanical joint with the remainder of the pavement
- low shrinkage to ensure the waterproof integrity of repair
- high flowability to ensure complete coverage with no voids
- convenient mixing and use characteristics to ensure uniform and consistent application
- Ability to perform in a wide range of operating temperatures to extend use of the process; and non-hazardous impact on crews and public
- the bonding agent needed to achieve an effective coupling or 'structural bonding' between the core and the pavement in such a manner that the road would regain its design ability to share and transfer the effect of traffic loading from one section to another

The Golder Report

http://www.keyhole-technology-research.org/PDFs/GolderReport.pdf

The Golder Report spanned the period 1992–1996 and encompassed a series of field trials and laboratory tests on more than 20 potential bonding materials. It resulted in the selection of a single process, cementitious bonding compound (now Utilibond), which had been specially designed for the process. Golder continued to monitor the effectiveness of the process for a period of ten years and in April 2003 reported that:

'The lab trials and previous demonstrations on the rotary cutting method have shown that the pavement coupon has been bonded into the slab in such a manner that the loads of traffic are effectively transmitted to the remaining intact slab. Based on trials carried out at our testing laboratory in Whitby and our in-field performance observations, we are satisfied that the equipment, procedures and materials [including Utilibond] developed and used by Enbridge Gas Distribution over the last 10 years will ensure satisfactory long term performance of pavement reinstatement.' (1)

The Golder Report is the only ten-year longitudinal study to evaluate the effectiveness of a road reinstatement process by monitoring the degree of coupling between the undisturbed road structure and the newly restored utility cut.

Above: To test the effectiveness of the bond, Golder cut satellite core samples through the kerf of previously reinstated cores. These samples (right) showed perfect and complete bonding or adhesion of the Utilibond to both the surface of the core or coupon and the surface of the remaining pavement, as well as excellent 'cohesion' through the joint itself. The light grey line in the photograph is Utilibond, showing excellent bonding of the asphalt–concrete core (central area) to the undisturbed pavement (outer layer) with complete infilling of voids in pea gravel (bottom). The core, which is directly in the wheel path of a transit lane of this arterial road, showed no deflection from the time it was first reinstated in September 1995 (left) to December 2002 (centre) notwithstanding the fact that, during the seven -year interval, more than 145,000 transit buses and 13 million commercial and other vehicles have passed directly over the keyhole with no apparent weakening or other degradation of the reinstated core or the adjacent road system or paved surface.

Utility Road Cut Study
National Research Council Canada & U.S. Army Corps of Engineers, April 2004
http://www.keyhole-technology-research.org/PDFs/NRC-Toronto-Utility-Cut-Study.pdf

Subsequently, from 2000 to 2003, these impressive results were independently confirmed by testing by the Joint Utility Cut Study led by the **National Research Council of Canada** and the **United States Army Corps of Engineers**. A report on the results of a Field Investigation conducted in Toronto, Ontario, between October 2001 and April 2003 **(2)** which monitored and compared the performance of the excavation and restoration procedures involved in a conventional trench excavation and a cored and reinstated keyhole, did find that the keyhole repair outperformed the conventional rectangular utility cut by a substantial margin.

Surface and subsurface data collected from sensors embedded in both excavations and visual observations over the 18-month test period revealed that the restored keyhole performed better and caused less damage to the road system than the conventional rectangular utility cut performed with a road saw and backhoe and restored in a conventional manner with newly poured concrete and newly laid asphalt. Specifically, settlement and deflection had occurred along the wheel path in the conventional repair, and the material used to seal the joint had been lost through the action of traffic shortly after its application. These failures allowed the joint between the road and the repaired section to open and was considered to be the most likely cause of higher than normal levels of moisture at the bottom of the open cut compared with the keyhole cut. By comparison, the keyhole repair showed no distress, remained level with the road profile, and performed well throughout the life of the experiment, with no signs of cracking or separation in the bonding compound surrounding the core.

The smaller footprint of the keyhole was also credited with reducing the level of wheel-load stress transmitted to the underlying sections of the roadway compared with the standard cut, and the circular shape minimised the potential for the propagation of pressure or stress cracks in the corners of the repair.

Based on these findings, the Report on the Toronto Field Investigation concluded that

"the keyhole coring and reinstatement process was an effective restoration technique that should be encouraged whenever feasible to minimise the need for opening large trenches in the future. The keyhole cutting and restoration technique that was evaluated in the Toronto field experiment indicates that the process is practical and effective in reducing the potential for damaging the road. It is recommended that the keyhole application be encouraged whenever proven feasible."

Newmark Civil Engineering Laboratory of the University of Illinois at Urbana Champaign
Bond Strength and Performance Testing of Utilibond and Other Products, June 2003
http://www.keyhole-technology-research.org/PDFs/LangeReport.pdf

The fast strength gain and overall bond strength performance of Utilibond was independently confirmed in 2003 by testing at the **Newmark Civil Engineering Laboratory of the University of Illinois at Urbana Champaign (UIUC). (3)**

The comparative testing of three commercially available bonding materials concluded that:

'The Utilibond material was the only bonding material that demonstrated satisfactory performance in the 30 minute tests [where it gained sufficient strength to support a single wheel load of more than 50,000lbs (22,680kg)]. Since all three materials ultimately achieve high safety factors against core punch out, it is reasonable to emphasise attributes of performance such as rapid set time and workability. Rapid set time and workability are meaningful attributes in the field application, and effectively differentiate the performance of bonding materials for reinstatement of cores.'

Utilibond Strength and Performance Testing by Construction Technology Laboratories (2009)

http://www.utilicor.ca/downloads/pdf/November_2009_-_Approval_-_Illinois_DOT_Utilibond.pdf

In May 2009, the bond strength of Utilibond was tested by **Construction Technology Laboratories (CTL**), an American Association of State Highway and Transportation Officials (AASHTO) approved testing facility, as part of the certification process for the **Illinois Department of Transport**. In their test of Bond Strength Using the Slant Shear Method (ASTM C 882), CTL reported that the fracture pattern revealed in the tests indicated that the bond formed by Utilibond was actually stronger than the pavement itself.

'Samples had fractures occurring through the bonding and substrate material. The fracture pattern resulted in a well-formed cone on one end, vertical cracks running through the caps, and no well-defined cone on the other end. This fracture pattern for this test indicates that the bond material is stronger than the substrate' (4)

Municipal Approval and Standard, City of Toronto, November 2007

http://www.toronto.ca/engineering/mcr/pdf/appendix_e.pdf

The UIUC findings, together with the results of the Joint Utility Cut Study form the basis of the approval of the process by the **City of Toronto** and its promulgation in November 2007. **TS 4.70: Construction Specification for Keyhole Excavation and Permanent Reinstatement of Keyhole Cores (5)** is the first comprehensive set of acceptance and performance standards for the keyhole coring and reinstatement process in North America. The Standard is far reaching and comprehensive.

The maximum diameter of the core is specified to be 460mm or 18inches, but, with prior approval of the city larger cores up to 610mm or 24 inches in diameter, or overlapping cores, may also be cut. This is important, because some locates may be a little off or a larger opening may be required to perform the repair work (see Figure 6). The minimum depth of asphalt or flexible pavements in which the process may be employed is fixed at 100mm or four inches. There is no thickness limitation on other types of pavement or sidewalks. The Standard also requires that the core be cut with equipment that is capable of accurate vertical adjustment, to ensure that the core is cut in an alignment perpendicular to the horizon.

A central part of the Standard establishes minimum performance criteria for the high-strength bonding material to be used to bond the keyhole core or coupon back into the pavement. To be approved, the bonding material must be capable of generating a waterproof bond that, within 30 minutes of application at 708F (218C), achieves an equivalent traffic loadable condition at least two times greater than the AASHTO H-25 standard or 30,000lbs (13,600kg).

1. Golder Associates Ltd (2003), 'Laboratory testing of new and improved bonding compound (Utilibond) and investigation of previously repaired pavement keyhole restoration techniques', Golder Associates Ltd, Toronto, Ontario. http://www.keyhole-technology-research.org/PDFs/GolderReport.pdf

2. National Research Council of Canada and United States Army Corps of Engineers (2004), 'Road utility cuts field investigation, Toronto Site', Report No: B- 5506.25, Research Précis. http://www.keyhole-technology-research.org/PDFs/NRC-Toronto-Utility-Cut-Study.pdf

3. Lange, D.A. (2003), 'Performance of Utilibond and other bonding compounds during the first two hours', Department of Civil Engineering, University of Illinois at Urbana-Champaign. http://www.keyhole-technology-research.org/PDFs/LangeReport.pdf

4. Construction Technology Laboratories, Skokie, IL (2009), 'Project No. 395377, ASTM C 928 Testing for Utilibond', 26th May. (http://www.utilicor.ca/downloads/pdf/November_2009_-_Approval_-_Illinois_DOT_Utilibond.pdf)

5. City of Toronto Transportation Services (2007), Standard construction specifications TS 4.70: Construction specification for keyhole excavation and permanent reinstatement of keyhole cores', November. http://www.toronto.ca/engineering/mcr/pdf/appendix_e.pdf

Adhesion and Cohesion

Adhesion: When surfaces are held together by interfacial forces, they are said to show good adhesion. Good adhesion requires very close contact. In the case of adhesive bonding this is achieved by flow of the bonding agent into the surface of the substrate. Adhesion strength is the force required to pull the adhesive clearly from the surface.

Cohesion: Cured adhesives or bonding agents, like other materials, can also be characterized by their internal strength, or the force required to cause permanent deformation, i.e. to break the bond. To differentiate from adhesion, cohesive strength of adhesives and substrates is used for this internal strength as shown.

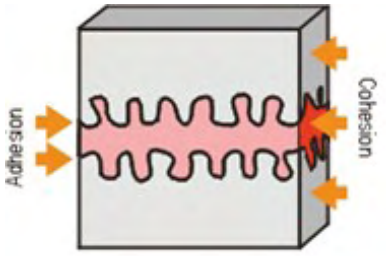


Figure 1: The types of forces in an adhesive joint. Good adhesion and cohesion are required to achieve high performance joints. Adhesives and bonding agents typically have a flow phase when they are applied, building up adhesion, followed by a hardening phase during which the cohesive strength builds up.

Structural Bonding

Structural bonding is the name given to a bond where it forms a joint that performs a load bearing function. This means that forces in a structure may be transmitted from one member to another through the joint. This force would be taken up by the bonding agent and spread or transmitted to the next member. This is the type of bonding that is important in a pavement repair where the end result is to reinstate the capacity of the pavement to perform as a load bearing system.

Golder Associates Study (1992-2002)

Golder Associates is an international engineering firm that provides science and engineering consulting services in support of environmental, industrial, natural resources, health and civil engineering projects. Golder monitored the development of the Enbridge rotary coring and pavement reinstatement system on a longitudinal basis between 1992 and 2002. According to Golder, to be effective in the long term reinstatement of pavements, the bonding agent needed to achieve an effective coupling or "structural bonding" between the core and the pavement in such a manner as the road would again share the effect of traffic loading.

The Golder study encompassed a series of field trials and laboratory tests on a broad cross section of potential bonding materials undertaken over the period 1992 to 1996 and resulted in the selection of a proprietary bonding compound specially designed for the process.

Ten years later, in October of 2002, a follow up study was commissioned to confirm previous results over a longer "in ground" period and to update performance data on the current version of Utilibond™ which is the third generation of the compound originally selected for the process. (See: Golder Associates Ltd., Report on Laboratory Testing of New and Improved Bonding Compound (Utilibond™) and Investigation of Previously Repaired Pavement Keyhole Restoration Techniques, Toronto, Ontario, April 21, 2003.

Figure 2

Figure 2. Satellite core samples taken through bonded area of reinstated core. The light gray line is *Utilibond* showing excellent bonding of asphalt-concrete core (central area) and undisturbed pavement (outer layer) with complete infilling of voids in pea gravel (bottom). (See: Golder Report).

To test the effectiveness of the bond, Golder cut satellite core samples through the kerf of previously reinstated cores as shown in Figure 2. These samples showed perfect and complete bonding or adhesion of the Utilibond to both the surface of the core or coupon and the surface of the remaining pavement as well as excellent "cohesion" through the joint itself.

The Golder study is the only ten-year longitudinal study to evaluate the effectiveness of a road reinstatement process by monitoring the degree of coupling between the undisturbed road structure and the newly restored utility cut. It concluded that:

"The lab trials and previous demonstrations on the rotary cutting method have shown that the pavement coupon has been bonded into the slab in such a manner that the loads of traffic are effectively transmitted to the remaining intact slab. Based on trials carried out at our testing laboratory in Whitby and our in-field performance observations, we are satisfied that the equipment, procedures and materials [including Utilibond™] developed and used by Enbridge Gas Distribution over the last 10 years will ensure satisfactory long term performance of pavement reinstatement."

Multiresistant Bonding

Not all adhesively bonded joints are solely structural. Multiresistant bonding is the use of adhesives where the joint is also required to withstand other environmental forces such as temperature cycling and vibration and resist the infiltration of water.

In the context of pavement repairs, to prevent infiltration of ground water through the perimeter of the cut that can washout the sub grade and result in premature degradation or failure of the pavement, the bond must not only be strong, but it must be waterproof.

Here again the effectiveness of Utilibond, as a bonding agent, was demonstrated in independently monitored field tests conducted by the National Research Council of Canada and the U.S. Army Corps of Engineers. (See: National Research Council of Canada, Road Utility Cuts: Report of Field Investigation, Toronto Site, April 2004).

Restoration of Utility Cuts Study (2005)

The "Restoration of Utility Cuts" project is a joint effort involving a number of North American cities, utility companies and U.S. State departments of transportation. The objective of the project was to develop a guide for best restoration practices based on sound engineering principles. As part of this study an experiment was conducted in Toronto using two cut sections -- a conventional transverse trench and a keyhole.

The report, scheduled to be released in June 2005, discusses results of in-situ testing and data collected from sensors installed in the restored cuts covering a wide range of engineering parameters and environmental conditions. In situ tests covered quality control tests included in City specifications. Sensor data was collected in four visits to the site where a test truck and the FWD device were used to load the test sections.

Both the conventional cut and the keyhole were instrumented to monitor traffic-induced stresses and moisture conditions in the lower layer of the pavement associated with this restoration procedure. After placement of sensors in the sand layer, unshrinkable fill was poured directly from the agitator truck into the excavation and brought up to the level of the pavement. Unshrinkable fill was used in both trench and keyhole restorations.

Road condition data collected prior to construction was used to establish a reference for tracing changes associated with cutting (trench and keyhole) and quality of construction. After the reinstatements, damage survey visits and inspections were conducted on three occasions: (1) October 2001, after completion of temporary restoration, (2) May 2002, following the final assessment of the performance of the temporarily restored trench prior to the second restoration stage and (3) April 2003, when the final assessment of the permanent restoration stage was performed.

Observations made during these site visits noted that:

- There were noticeable failures in the conventional cut. The conventionally repaired joint between the road and the cut opened. The location of this joint separation coincided with visible settlement in the trench along the wheel path. The material used to seal the joint was lost under the action of traffic as a result of shear flow or pullout of the sealant and there are indications that the sand cover and surrounding clay in the Toronto restored cut were exposed to higher than normal levels of moisture (compared with the keyhole). There were no defects noted in the keyhole cut.

- There were no defects noted in the keyhole cut. The keyhole section established on October 2001 continued to perform well throughout the life of the experiment. The surface of the restored keyhole remained at level with the road profile. The grout [*Utilibond*] surrounding the AC/PCC plug remained intact (no cracking or separation).

The report observed that keyholes are currently being used to access buried facilities to perform the intended utility job reducing the need to cut large openings in road and that the surface and subsurface data collected from the keyhole established in the Toronto experimental site revealed that the restored keyhole performed well and resulted in no damage to the road. Based on these findings the report concluded:

- "Considering the area of a tire print of heavy trucks in contact with the road surface, the keyhole opening resulting from coring is quite small (18 inches in diameter). As a result, low stresses are transmitted to the underlying sections of the restored keyhole."
- Based on basic rules of mechanics, a circular cut shape in the AC is ideal for preventing propagation of cracks into the surrounding road area.
- "Effective equipment was developed for performing cutting and excavation with no potential for causing damage. Cutting is performed by coring and removal of existing road material is performed by vacuuming material from inside the keyhole."
- The plug consisting of PCC and AC layers is removed with great care using dedicated equipment and later reinstated at the surface.
- Research conducted by Enbridge Gas Distribution Inc. resulted in developing an effective grout [*Utilibond*] for use in the restoration process. The grout is used to attach the PCC/AC plug to the road and for sealing the joint. In the Toronto keyhole section, the grout performed effectively throughout the life of the experiment (September 2001 to April 2003) with no signs of loss of material or separation of the joint.
- "The combination of keyhole construction technique and unshrinkable fill produced an effective restoration technique that should be encouraged whenever feasible to minimize the need for opening large trenches in the future."

In essence the NRCC/USACE Report confirms that the keyhole excavation and reinstatement method using *Utilibond* is superior to conventional methods. There is no deflection or settlement of the reinstated core (i.e. *effective structural bonding*) and no infiltration of ground water (i.e. *effective multiresistant bonding*).

The Mechanics of Bonding

According to Dr. David Lange*, the mechanical performance of the bonding material is one of the most important factors in achieving long-term performance in the reinstatement of cores in pavement. It is well known that repair or bonding materials achieve their primary bond through mechanical interlock with the surface or microstructure of the substrate.

It is important that the bonding material mechanically engage with the surface irregularities or penetrate the pore structure of the concrete.

To be effective, the solid particulate in a dry-base bonding agent needs to be fine enough, when mixed with water, to establish an intimate bond with the surfaces to be bonded. Coarser grouts will not work as well and, while they may exhibit good compressive strength or appear able to fill the kerf and stabilize the core, they will lack the adhesive qualities of a good bonding agent.

Traffic pressure and vibration may cause premature adhesive bond failure in these grouts that will deprive the joint of vertical support and the ability to transfer transverse loading across the joint, as well as permitting the infiltration of water into the sub-grade.

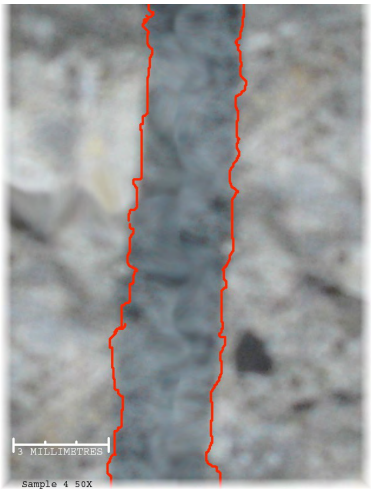
When liquefied by the addition of water, the chemical composition and fine granular structure of *Utilibond* results in a lower surface tension of the bonding material relative to the solid surfaces of the concrete substrate. Surface tension is the force at the surface of a liquid due to adhesive forces of the liquid molecules for the solid walls of a container (in this case the surface of the core and the surrounding pavement) and the attractive forces of the molecules of liquid for each other. When the adhesive forces of the molecules for the solid walls are greater than the attractive forces between the liquid molecules, then the liquid will wet the solid surface. In porous solids like cement paste, concrete or asphalt, the liquid will wet the exposed surfaces and will be drawn into intimate proximity with the surface structure (densification) under forces known as capillary tension. The extent of penetration of a liquid into pore structure which contributes to densification is governed by the strength of capillary tension forces and the liquid viscosity.
Unlike *Utilibond,* which *is a bonding agent*, in typical grouts these forces are very weak or non-existent.

* David A. Lange, Ph.D., P.E., FACI, is a recognized authority in the area of civil engineering materials, cement microstructure property relationships, fracture mechanics of concrete, fiber reinforced concrete, and interfacial bond in cement-based and masonry materials.He is the Principal Investigator or Co-Principal Investigator for the Illinois Department of Transportation, The National Science Foundation, Master Builders, Inc., Applied Sciences, Inc., Federal Aviation Administration, FAA Center of Excellence, and the NSF Center for Advanced Cement Based Materials.
Dr. Lange also serves as the Chairman of the Cements Division of the American Ceramic Society, Chair of ACI Committee on the "Materials Science of Concrete," and is Associate Editor of the ASCE Journal of Materials in Civil Engineering

The relationship of viscosity with time is one way of understanding the evolution of *Utilibond* from a liquid to a solid. As a liquid with a low viscosity it can wet the concrete surface and be drawn into very close contact with the concrete pore structure by capillary forces. The densification process of *Utilibond* will cease when the material hydrates.

Utilibond is a multi-component, super-plasticized, limecement mortar specifically engineered and designed for bonding cement and asphalt cores back into the original substrate. Unlike typical "grouts" which are moderate strength fillers used for filling cavities, voids and cracks, *Utilibond* contains special additives designed to enhance the bonding performance of Portland cement-based materials.

This unique blend of components results in high cohesive strength through high density and low water absorption and improves the mechanical performance, workability, adhesion and resistance to harsh environmental exposures of the product such as freeze-thaw scaling.



Utilibond microstructure (illustrated)

Bond Microstructure:

An examination of the microstructure of the interface between *Utilibond* and the concrete substrate of the core and the surrounding pavement shows a very strong and high quality adhesive and cohesive bond.

The strength of this bond was demonstrated in the "no bottom" experiments of the Gas Technology Institute conducted in the Fall of 2003.

GTI "No Bottom" Core Test *(2003)*

In this test, which is still in progress, GTI restored a cored hole without backfill using *Utilibond.*

The original GTI study plan was to demonstrate the effectiveness of backfill compaction as a factor in keyhole reinstatement. They planned to use various levels of compaction — good — fair — poor and no backfill at all. They started with the *no backfill* experiment in which they cored and vacuumed an 8 inch deep hole in asphalt, inserted a temporary false bottom consisting of a cardboard plate suspended by strings on to which they placed pea gravel and then *Utilibond* and reinstated the core *(See Figure 4)*. After the *Utilibond* set they released the string supports of the false bottom and began testing the ability of the *Utilibond* to support a suspended core — with no backfill under it.

To do this they passed their 9,000 lb AASHTO standard test vehicle over the core and to their surprise it sustained ***more than 40,000 passes*** before giving way and settling about 20 millimeters on one side.


False bottom hole


Utilibond poured into hole


Setting the core


Loading machine 40,000 + passes

As some of the failure appears to have occurred in the asphalt outside the bond and the *Utilibond* layer in that area remained intact, the technicians were unable to determine whether or not it was failure of the asphalt around the core that occurred first, there being no bridging strength in asphalt, causing undue torque on the core that then caused the failure in the bond, or whether it was failure of some areas of the kerf that may not have been fully impregnated with bonding agent when the core was originally set into the hole. For obvious reasons, when reinserting the core, the technicians were reluctant to aggressively manipulate the core (as would have been done to distribute the *Utilibond* in a normal reinstatement) for fear of destroying the false bottom.

Although the test may have been compromised by possible defects in the actual reinstatement procedures, and the actual cause and effect of the failure speculative, the experiment did prove that *Utilibond* was more than just a grout that infills the kerf of the core like a traditional grout.

Utilibond is, as designed and engineered, a Pavement Bonding Compound. The GTI test demonstrated that *Utilibond* had significant adhesive and cohesive bonding strength to support an otherwise unsupported 8 inch core of asphalt exposed to more than 40,000 passes of the 9000 lb. AASHTO standard test vehicle in which the wheel path passed directly over the core. That is equivalent to more than seven years of traffic on a non-arterial road. This test also tends to support anecdotal evidence of *Utilibond* reinstated cores withstanding underground washouts that undermined the entire pavement area resulting in a sinkhole. Notwithstanding the long-term lack of support resulting in catastrophic sub-surface failure, the *Utilibond* reinstated core demonstrated no deflection from the surrounding pavement layer whatsoever.

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Conclusion

The successful adhesive and cohesive bonding performance of *Utilibond* in these tests is due both to the fineness of its granular structure and proprietary additives that contribute to lower surface tension when in liquid form and accelerated strength gain during hydration.

When initially mixed, *Utilibond* has a low viscosity and a low surface tension that allows capillary forces to draw it very close to the surface structure of the concrete and fully engage the underlying substrate where its very high density and super-fast strength gain result in a very strong bond capable of supporting 52,600 lbs in less than 30 minutes.

When used for reinstatement of cores, these properties result in a waterproof joint that reintegrates the core with the roadway to restore the structural performance of the original roadway as a load bearing system, as was found by the experimentation and observations of Golder Associates.

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Model Municipal Regulatory Language for Coring and Reinstatement

City of Toronto TS 4.70 Construction Specification for Keyhole Excavation and Permanent Reinstatement of Keyhole Cores (November 2007)	**Maricopa Association of Governments Uniform Standard Specifications for Public Works Construction, 355: Utility Potholes-Keyhole Method** (August 2010)
Excavation Method	**Excavation Method**
03: Keyhole Excavation: means the operation of coring a circular hole through the roadway pavement or sidewalk using diamond drilling/coring equipment to remove the asphaltic concrete or concrete courses of flexible pavement rigid pavement, composite pavement and sidewalk and the removal of materials from the ground by water or air vacuum excavation method, and its disposal. 07.02: Cutting of existing pavements shall be performed with an approved keyhole-coring saw. The vertical alignment of the keyhole-coring saw shall be perpendicular to the horizon, and the cutting shall be extended to the full depth of the existing structure.	355.1: This specification covers the requirements for coring, vacuum excavation, backfilling, and reinstatement of the asphalt core into asphalt pavement. 355.2: Excavation requires coring a circular hole through asphalt pavement using drilling/coring equipment and removal of the intact asphalt pavement core. The vertical alignment of the coring operation shall be perpendicular to the horizon and cutting shall be extended the full depth of the existing pavement section.
Core Size	**Excavation (Core Size)**
07.02: Keyhole Coring: Pavement and sidewalk cuts for vacuum excavation in keyhole coring shall not be greater than 460 mm (18 in) in diameter. Larger cores, up to 610 mm (24 in) in diameter, or overlapping cores, or cores closer than 1 metre (3.3 ft) from each other, a joint or any longitudinal or transverse crack greater than 3 mm (1/8 in) width may be allowed only with the prior approval of the City. Keyhole cores will not be permitted in flexible pavements where the asphaltic concrete is less than 100 mm (4 in) thick.	355.2: Pavement cores shall not be greater than 24 inches in diameter, shall not be spaced closer than 3 feet between cores (edge to edge), shall not contain a joint or any pavement cracks greater than 1/8-inch wide, and shall only be obtained from pavements where the asphalt concrete section is at least 4 inches thick.
Keyhole Coring (Surface Restoration)	**Pavement Restoration**
07.02: The surface cut by keyhole coring shall be restored to its original condition with the reinstated core flush with the existing surface, and with the structure of the restored surface matching existing concrete surfaces and asphaltic concrete surfaces. Excess bonding material shall be removed from the restored surface. A "patched" appearance is visually unacceptable to the abutting properties, and efforts should be made to avoid this in surface restoration wherever possible. 07.02: All construction and maintenance work performed by the Applicant or its contractor using keyhole excavation method shall be carried out in such a manner that the pavement or sidewalk surfaces worked upon are restored and colour matched as close as possible to, if not better than, the original condition of the surface.	355.4: The pavement surface shall be restored to its original condition by setting the reinstated pavement core flush with and in its original orientation. 355.4: Excess bonding material shall be removed from the restored pavement surface. A "patched" appearance shall be avoided in surface restoration wherever possible.

Model Municipal Regulatory Language for Coring and Reinstatement

Bonding Material for Keyhole Cores	Asphalt Pavement Core Bonding Materials 708
03: Bonding Material: means a single component, cementitious, rapid hardening, high strength, concrete repair material, used to bond the undamaged keyhole core to the pavement from which it was originally removed. 05.02: Bonding material shall be impervious to water penetration at the joint after application. The bonding material is required to securely bond the undamaged keyhole core to the pavement or sidewalk and to fill the annular space at the joint. 05.02: Specifications for the bonding material shall be submitted to the City for review and approval before a bonding material is used. The specifications will include results of laboratory and field testing in accordance with TS 4.70.05.02.01 and TS 4.70.05.02.02. 05.02: In testing, the bonding material shall, within 30 minutes at 21°C, reach an equivalent traffic loadable condition that is at a minimum two (2) times greater than the AASHTO H-25 standard on simulated loading slabs prepared to yield a standard mix with a 28 day compres-sive strength of 35 MPa using 19 mm minus aggregates	355.4: Bonding agent meeting the requirements of Section 708 shall be used for pavement core reinstatement. 708.2: Bonding material shall be a single component cementitious, rapid hardening, high strength, waterproof bonding agent conforming to the physical properties shown in Table 708-1. 708.2: Bonding material shall be impervious to water penetration at the joint after curing. 708.2: The bonding material is required to securely bond the asphalt concrete core to asphalt concrete pavement and to fill all voids between the core and pavement and within the core. 708.3:Specifications and test results for the bonding material shall be submitted to the Agency for review and approval before use. 708.2: Bonding material shall, within 30 minutes at minimum ambient temperature of 70 degrees F., allow an 18" diameter core to support a traffic load equivalent to at least three (3) times the AASHTO H-25 standard wheel load.
Defective Keyhole Cores	**Deficiencies (Defective Cores)**
07.05: Where the keyhole core is found to be fractured or defective upon removal, or becomes damaged after removal and prior to reinstating the keyhole cuts, the defective or damaged core shall not be used to reinstate the pavement. A core that is fractured in the vertical plane is considered to be defective and shall not be used to reinstate the pavement. If another equivalent core of sound condition and matching existing pavement of the same diameter, depth and composition as the defective core is available, it may be reinstated in substitution of the defective core.	355.6: Where the pavement core is found to be fractured or defective upon removal, or becomes damaged after removal and prior to reinstating, the defective or damaged core shall not be used to reinstate the pavement. Pavement repair shall be performed in accordance with Detail 212, Type A Pavement Repair. **NOTE: No core substitution allowed at present**.

Model Municipal Regulatory Language for Coring and Reinstatement

Unacceptable Cores	**Unacceptable Cores**
08.02: A keyhole core is considered unacceptable when one of the following conditions exist: a) The keyhole core contains any vertical cracks wider than 3 mm (1/8 in) extending full depth or partial depth through the core; or b) Any deteriorated piece of the keyhole core is larger than 10 percent of the overall area of the keyhole core 07.05: If the keyhole core is limited to the horizontal delamination of two or more successive layers of asphalt concrete, that core may not be considered to be defective if the layers are capable of being rebonded to each other with the bonding compound during reinstatement.	355.6:A pavement core is considered unacceptable when one of the following conditions exist: a) The core contains any vertical cracks wider than 1/8-inch extending full depth or partial depth through the core; or b) Any deteriorated piece of the core is larger than 10 percent of the overall area of the core. c) Two or more successive layers of asphalt concrete in the core become horizontally delaminated and cannot be rebounded to each other with the bonding compound.
Core Removal & Replacement of Unacceptable Cores	**Removal & Replacement of Unacceptable Cores**
08.02: All unacceptable keyhole cores shall be removed, disposed of offsite, and a matching replacement core shall be installed or a temporary asphalt patch of HL-1 shall be constructed at the keyhole core location. In the case if a defective keyhole cores, this location shall be restored according to TS 4.70.07.05. The keyhole core repair work shall all be completed at the Applicant or its contractor's expense.	356.6 All unacceptable pavement cores shall be removed from the job site. 355.6: Pavement repair shall be performed in accordance with Detail 212, Type A Pavement Repair.
Surface Tolerance	**Surface Tolerance**
08.01: The reinstated core shall be flush and level with the adjacent pavement. No gap, attributable to the positioning of the core, should be found between the bottom of the straightedge and the surface of the pavement when a 1.0 m (3.3 ft) long straightedge is placed in any direction on the surface of the keyhole cores of sidewalks or pavements, except across the crown or drainage gutters.	355.5: The reinstated core shall be flush and level with the adjacent pavement. Gaps attributable to the positioning of the core shall be less than 1/16-inch between the bottom of a minimum 3-foot long straightedge and the surface of the pavement in any direction on the surface of the key-hole core, except across the pavement crown or drainage gutters.
Keyhole Orientation	**Keyhole Orientation**
07.04: To ensure that the keyhole core is placed in the same orientation as originally constructed, the Contractor shall place a temporary mark (paint or chalk) to help align the keyhole core.	355.2: Contractor shall place a temporary mark (paint or chalk) on the pavement core and adjacent pavement prior to cutting to insure that the pavement core when replaced will have the same orientation as found in the original pavement.

Model Municipal Regulatory Language for Coring and Reinstatement

Restoration Timing &Temporary Road Plates	Restoration Timing &Temporary Road Plates
07.04: Permanent Surface Restoration with Keyhole Cores Where possible, the Applicant or its contractor must reinstate the keyhole core, complete with the bonding material immediately or within 24 hours of cutting the existing pavement unless special permission has been granted by the City Inspector. 07.06: In the event when a keyhole cut cannot be reinstated within 24 hours of cutting, the opening shall be covered with an approved form of an appropriately-sized, circular steel road plate fitted with a collar that, when inserted into the keyhole, will prevent the hole cover from tipping, tilting, bouncing or spinning out of the hole in all kinds of the traffic conditions; or a counter-sunk steel plate set flush with the surface of the pavement and overlapping the cut by no less than 300 mm on all sides. The steel plate must have a non-skid surface and must provide a safe driving surface. This plate must be secured to the pavement and has sufficient thickness and strength to support the traffic without movement or bouncing. An asphalt mix shall be used to jam the plate into the pavement along all edges.	355.4: The contractor shall reinstate the pavement core within 24 hours of cutting the pavement. 355.4: Holes left open longer than 24 hours after cutting shall be covered with an approved steel road plate capable of supporting traffic loads. The steel plate must be rounded with a fitted collar that, when inserted into the hole, will prevent the steel plate from tipping, tilting, bouncing or spinning out of the hole under traffic conditions. An asphalt mix shall be used to ramp pavement up to the steel plate along all edges.

SPECIFICATIONS REVISIONS
EFFECTIVE 01/01/11

SECTION TITLE AND REVISION SUMMARY 215 “Keyhole Pothole Excavation and Backfill" - To allow for keyhole type pothole excavation and repair.

VOLUME I
UNIFORM STANDARD DRAWINGS REVISIONS
EFFECTIVE 01/01/11

506 "Utility Pothole Repair" – New standard drawing to allow for keyhole type pothole excavation and repair

SECTION 215 KEYHOLE POTHOLE EXCAVATION AND BACKFILL

DESCRIPTION

215.01.01 GENERAL

A. This specification covers the requirements for keyhole coring, vacuum excavation, backfilling, and reinstatement of the keyhole core in asphalt or concrete pavements to allow for underground utility repairs and underground exploratory potholing.
B. Quality control field inspection and testing requirements including frequency shall be in accordance with Contracting Agency requirements.

215.01.02 DEFINITIONS

A. **Keyhole coring:** The operation of coring a circular hole through the roadway pavement using diamond core drilling equipment.

MATERIALS

215.02.01 GENERAL

A. The material and placement requirements in the pipe zone and final backfill area shall be in accordance with Section 208, “Trench Excavation and Backfill.”
B. Pavement keyhole cores removed shall either be removed from the work site or stored in a safe and secure on-site location. The cores shall be made readily available for restoring the pavement after backfilling is complete and approved.
C. **Bonding Agent**: The bonding agent shall be a single component cementitious, rapid hardening, high strength, waterproof bonding agent conforming to the physical properties shown in Table 1.

1. The bonding material shall be impervious to water penetration at the joint after application.
2. The bonding material shall securely bond the undamaged keyhole core to the pavement and shall completely fill the annular space at the joint.
3. The bonding material shall, within 30 minutes at an ambient temperature of 70 degrees Fahrenheit, allow the core to support an equivalent traffic load condition of at least three (3) times the AASHTO H-25 standard.
4. The bonding material shall be Utilibond, manufactured by Utilicor Technologies, Inc., or an Engineer approved equal.

Table 1:

Bonding Material Properties

Property	ASTM Test Method	Requirements
Bond Strength (Slant Shear), psi (70 degrees F., 30 minute cure)	C882	200 min.
Compressive Strength, psi (70 degrees F., 60 minute cure)	C109	1500 min.

CONSTRUCTION

215.03.01 POTHOLE EXCAVATION, GENERAL

A. The vertical alignment of the keyhole coring shall be perpendicular to the horizon, and the cutting shall extend to the full depth of the existing pavement section.
B. Unless otherwise approved by the Engineer, keyhole cores shall not be greater than 24-inches in diameter. Adjacent cores shall not be closer than 3 feet from each other (edge to edge), shall not contain a joint or any pavement cracks greater than 1/8-inch wide, and shall not be performed in pavements where the section is less than 4-inches thick.
C. Coring shall be performed with a keyhole coring saw.
D. The Contractor shall place a temporary mark on the keyhole core prior to cutting to insure that the removed section is replaced in the same orientation as originally found in the pavement.
E. Soils within potholes shall be removed by air/vacuum extraction methods to expose utilities. The zone of soil removal shall remain essentially within a vertical plane extending below the edges of the removed pavement.
F. The Contractor shall remove all materials excavated from the site.

215.03.02 POTHOLE BACKFILL AND COMPACTION

A. The backfilling of each zone shall be completed in accordance with Section 208, “Trench Excavation and Backfill.” Unless otherwise approved by the Engineer, the backfill material shall be placed in maximum 10-inch loose lifts.
B. Backfill compaction quality shall be determined by use of a compression wave amplitude monitoring device manufactured specifically for the purpose of measuring soil compaction. This device shall measure the compression wave amplitude as compaction progresses using below-grade disposable piezoelectric transducer wave sensors and an above-grade electronic monitor. The device shall signal the operator of successful compaction when the compaction wave amplitude becomes asymptotic to continued compaction effort for each lift.
C. Backfill soil shall be placed with a moisture content within three percent of optimum moisture content. Moisture content shall be determined in accordance with AASHTO T217.
D. Place a disposable compaction sensor at the bottom of the first loose lift. A new sensor shall be placed for every 48-inches of compacted fill depth. Remove backfill soil and sensor if the disposable sensor fails during compaction and repeat repairs with a new sensor.
E. Mechanical compaction on each lift shall be continued until the electronic monitor signals that compaction is complete. A new lift shall not be placed until a positive signal has been received. Remove backfill soil and sensor if the monitor does not give a positive compaction signal after repeated compaction work.

215.03.03 PAVEMENT RESTORATION

A. The surface cut by keyhole coring restored to its original condition with the reinstated core flush with and in the original orientation as the existing surface, matching existing pavement surface appearance.
B. Excess bonding material shall be removed from the restored surface. A patched appearance shall be avoided in surface restoration wherever possible.
C. Unless otherwise approved by the Engineer, the Contractor shall reinstate the bonded keyhole core within 24 hours of cutting the pavement. Openings allowed to be left open greater than 24 hours shall be covered with an approved steel road plate capable of supporting traffic loads, and in accordance with Subsection 208.03.21, “Cutting and Restoring Street Surfacing.”
D. **Surface Tolerances**: The reinstated core shall be flush and level with the adjacent pavement. Gaps attributable to the positioning of the core shall be less than 1/16-inch between the bottom of a minimum 3-foot long straightedge and the surface of the pavement in any direction on the surface of the keyhole core.

215.03.04 DEFICIENCIES

A. Where the keyhole core is found to be fractured or defective upon removal, or becomes damaged after removal and prior to reinstatement, the core shall not be used to restore the pavement. The pavement at damaged keyhole core locations shall be cut and a permanent patch shall be installed in accordance with Subsection 208.03.21, “Cutting and Restoring Street Surfacing.”
B. A keyhole core shall be considered unacceptable when one of the following conditions exist:
1. The keyhole core contains any vertical cracks wider than 1/8-inch extending full depth through the core; or
2. Any deteriorated piece of the keyhole core is larger than ten percent of the overall area of the core; or
3. Two or more successive layers of pavement in the keyhole core become horizontally delaminated and cannot be re-bonded to each other with the bonding material.
C. All keyhole cores that are damaged or do not meet the surface tolerances shall be removed, and the Contractor shall cut and install a permanent patch in accordance with Subsection 208.03.21, “Cutting and Restoring Street Surfacing.”

METHOD OF MEASUREMENT

215.04.01 MEASUREMENT

A. Unless otherwise specified, the quantity of Keyhole Core repair will not be measured for payment, but shall be considered incidental to other items of work.

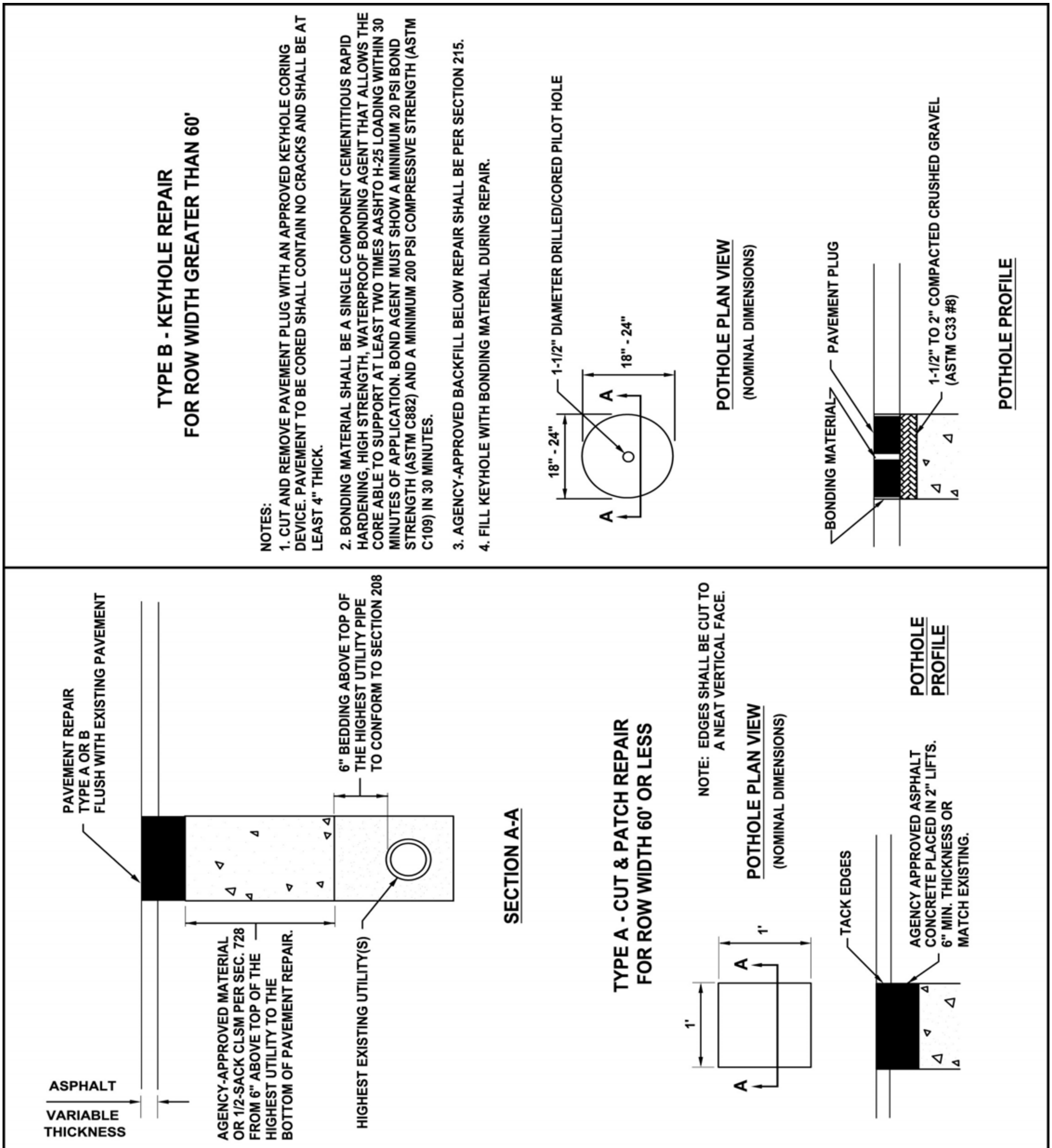
BASIS OF PAYMENT

215.05.01 PAYMENT

A. Payment for Keyhole Core Repair will be made only when required in the Special Provisions.

NOTE: The report of the Regional Transportation Committee for Southern Nevada creating this Standard suggests that they would like to have had at least two products that meet the specification. But subsequent inquiry by Officials indicated that only Utilibond met the requirements of overall strength and the strength gain time frame. The Standard provides for the substitution of an Engineer approved equivalent.

“Mr. Paul Judd, Regional Transportation Commission of Southern Nevada (RTC), explained that this item was a follow up to the prior agenda item. He went on to say that this particular item concerned the criteria for the materials and methods. He shared that the Utility Coordination Committee had made their approval conditional upon RTC staff members' attempts to find two sources of Utilibond to bond the keyhole back into the holes. He related that the RTC had conducted an industry-wide search and could not find a product with sheer strength equal to that of Utilibond. He further noted that certain other products could achieve compressive strength equal to Utilibond, but not in the same time as Utilibond. Mr. Judd concluded his statement by stating that the RTC had listed Utilibond as the sole source and noting that the California Department of Transportation had a sole source for this particular keyhole application.” RTC Report dated: 9/12/2010



SPECIFICATION REFERENCE		UNIFORM STANDARD DRAWINGS CLARK COUNTY AREA		
		UTILITY POTHOLE REPAIR		
		DATE 12-09-10	DWG. NO. 506	

Keyhole Coring and Reinstatement: An Upstream Green Technology for the Gas Industry
In addition to Downstream Green Technology, there is also a huge environmentally positive impact on Operations to be derived from using environmentally friendly operations and maintenance methods. These methods can significantly reduce the carbon foot print of gas maintenance and reduce atmospheric emissions of green house gases by shortening up the maintenance and repair process and reducing the consumption of millions of tons of asphalt and other paving materials as well as the disposal of millions of cubic feet of asphalt spoil every year in utility cut repairs. Gas utilities need to lead with their own behavior if they are going to be able to persuade their customers to use more energy e-cient appliances. To do so, utilities need to reduce their own carbon footprint in delivering that energy to the customer. A case in point is keyhole coring and reinstatement that is proven to *reduce the carbon footprint of typical utility cut repairs by up to 85 per cent.*

The Times are Changing
The utilization of traditional open-cut methods for the installation or repair of underground utilities has been common practice in the gas industry for many years. Today, natural gas operators are being tasked with the requirement of selecting a suitable construction method that not only offers the most economical solution, but also minimizes impact to the environment and reduces the upstream carbon footprint of gas operations.

Keyhole Coring and Reinstatement
Keyhole coring and reinstatement methods offer such a solution for installing and connecting new gas utilities and rehabilitating existing infrastructure. The use of several different types of construction equipment including jackhammers, concrete saws, backhoes, dump trucks, vacuum excavators, asphalt and cement delivery vehicles and pavement compactors, during open-cut construction and repair and the need for at least two road closings, invariably results in considerably more noxious emissions into the atmosphere compared with keyhole methods, which have minimal on-site equipment requirements -- a coring unit, a vacuum excavator and a hand-held pogo tamper compaction device -- and only require a single road closing to effect a permanent repair.

Not only does keyhole coring and reinstatement use fewer pieces of equipment than conventional excavation and restoration (see illustration below), but, because it reuses the same core of pavement to permanently repair the road-way after the underground work has been performed, there is no spoil to be disposed of and no need for additional paving materials. It is the production of these paving materials – concrete and asphalt – that is the largest source of U.S. carbon dioxide emissions, second only to fossil fuel consumption.

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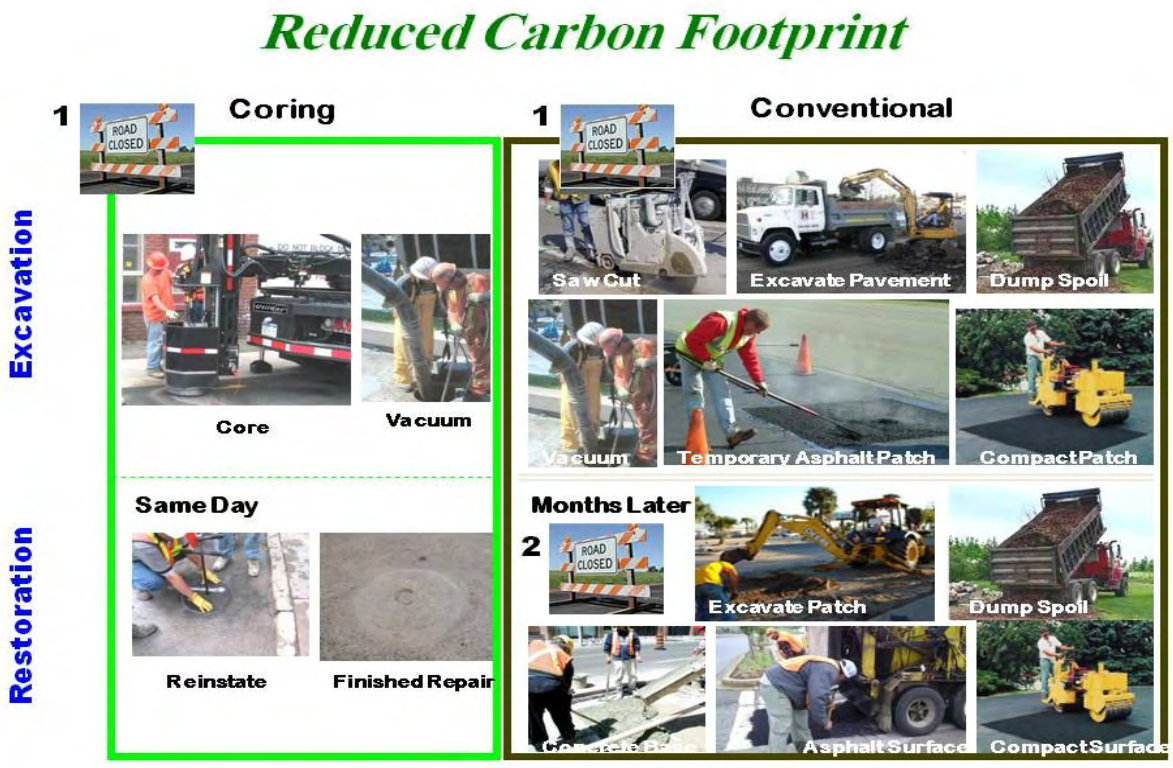


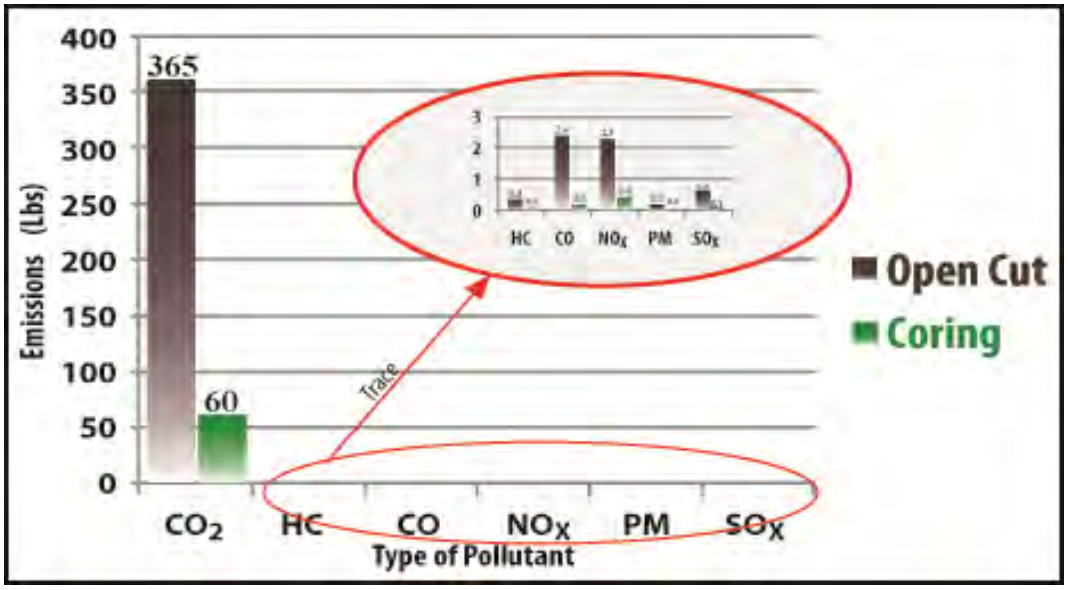
Moreover, because the keyhole core reinstatement is a permanent repair, there is no need to subsequently close the road again to remove and replace a temporary asphalt pavement patch with a permanent repair, thereby avoiding the emission into the atmosphere of additional volatile organic compounds from new asphalt pavement.

Smaller is Better

Last year in the U.S., more than 3.6 million pavement cut permits were issued nationwide for dierent sized utility cuts ranging from a 2 x 4 utility cut to a huge trench excavation for sewer work. It is estimated that 20-25% of those permits, or 800,000, were for utility cut excavations for work that could have been performed through an 18-inch or 24-inch diameter cored keyhole. If the keyhole coring and reinstatement process had been used in the more than 800,000 small hole utility cuts made every year in our nation's roads, it would have saved more than 2 million tons of asphalt concrete -- that's enough asphalt to repave 650 miles of 4-lane highway and would have eliminated the need to dispose of 27 million cubic feet of pavement debris or spoil – that's enough debris to -ll 200,000 dump trucks. Used nationwide, it would also have eliminated 2.8 million hours of work zone traffic delay and saved more than 1.9 million gallons of otherwise wasted fuel.

Carbon Footprint

The following chart, using the standard methodology for calculating carbon footprint and *eCalc*, the emissions calculator developed by Dr. Sam Ariaratnam and Vermeer Manufacturing*, which tracks engine emissions (CO2, CO, NOx, VOC, SOx) only -- shows that the Carbon Footprint from conventional open cut procedures is SIX TIMES GREATER than one produced by the coring and reinstatement option.



*Ariaratnam, Samuel T. Ph.D., P.E., Del E. Webb School of Construction, Arizona State University, Tempe, AZ; and Savage, Ed,, Vermeer Manufacturing Company, Pella, IA, "Methodology For Calculating The Carbon Footprint Of Underground Utility Projects", Proceedings of the North American Society (NASTT) and the International Society for Trenchless Technology (ISTT)International No-Dig Show, Toronto, Ontario Canada March 29 – April 3, 2009

Coring and Reinstatement Benefits

Southwest Gas Corporation uses the keyhole coring and reinstatement process throughout its operating areas in Arizona, California and Nevada. According to Byron Elkins, Manager of Operations Planning & Analysis:

"The keyhole process is cost-effective, results in a better pavement repair, is safer for the employees because they do not have to go down into the excavation, and is environmentally friendly. For us at Southwest Gas there are four key environmental benets to the Utilicor keyhole coring and reinstatement process. The rst is that it eliminates the massive amounts of energy that are normally required to produce, heat and transport new asphalt to the worksite. Second, because the process actually reuses the existing material to repair the road, it also eliminates the need to dispose of any pavement debris. Third, it prevents the release of toxic emissions that would otherwise occur during the drying process. And fourth, it reduces our carbon footprint."

Keyhole coring and reinstatement is a technology whose time has come for the gas industry and for our Planet.

Core Reinstatement Procedure

1) The core, or coupon, cut from the pavement using the keyhole coring equipment can be reinstated as a permanent repair using Utilibond after the hole has been properly backfilled and compacted. The first step of reinstating is to properly prepare/clean the cored hole. Wipe clean all cut surfaces of the core and walls of the hole with a clean, damp sponge to remove all loose cutting debris and particulate from the cut surface. Proper bonding depends on achieving a clean surface for the bonding agent to adhere to.

2) Line the bottom of the hole with a 1"- 2" deep bed of pea gravel. Because the pea gravel is added fill that was not present before, the backfill should be left approximately 2 inches lower than the base of the pavement. Undercut the bottom of the existing pavement in the hole by about 1" all around to allow the pea gravel to fill under the pavement. Utilibond will impregnate the pea gravel and create a solid base / plug for the core to bond to.

3) Using the core puller, lower the core back into the hole and check for level and flushness with the existing pavement. Adjust the pea gravel until the core is level with the surrounding pavement, and approximately 1/8" to 3/8" below the surface of the surrounding pavement. This process is referred to as "dry fitting" the core. This is an essential step to a successful core reinstatement. Once the Utilibond has been added to the hole and the core has been reinserted, you will not have a second chance to change its level to make the core level with the surrounding pavement. **Make sure it's done right the first time.**

4) Prepare the bonding compound by first removing the bag (s) of Utilibond from the pail. Add water to the level indicted on the outside of the pail. Do not exceed or reduce the amount of water. Exact proportions of water to Utilibond are crucial for effective performance. Use the 1-litre container supplied in all Twin Pack pails to achieve exact water proportions.

5) Carefully open the bag(s) of Utilibond, creating a clean opening though which to pour the Utilibond powder from.

With the mixing blade inserted into the bottom of the pail, slowly add the Utilibond powder to the water in the pail, while engaging the drill with the mixing blade.

6) Use the handheld drill and appropriate mixing blade, mix the bonding compound until it is smooth and flowing. (Mixing time is approximately 2- 3 minutes). Once mixed the Utilibond will appear smooth and creamy with a flow characteristic similar to that of pancake batter. **Do not add** additional water if the mixture looks dry at the beginning of the mixing process. Keep mixing and the Utilibond compound will "turn" after about one minute and begin smoothing out.

7) Carefully pour the entire pail of Utilibond permanent pavement bonding compound into the hole. Be careful not to disturb the layer of leveling pea gravel in the bottom of the hole while you pour the Utilibond in.

8) Slowly lower the core down into the hole, on top of the Utilibond compound. Move the core back and forth with the core puller, while tapping downward to allow the bonding compound to flow up through the cut spaces around the core (the kerf) and over flow slightly onto the surface of the pavement. Remove the core puller and allow the Utilibond to flow up through the centre hole. Apply gentle pressure to the top of the core, and ensure the core is level with the pavement by allowing the excess Utilibond to flow up to the surface from the kerf and the pilot hole. Use a flat trowel to clean up any excess Utilibond. Drag the flat edge of a trowel across the edge of the kerf to ensure that the core is flush with the rest of the roadway all around the circumference.

9) Carefully clean off the excess Utilibond from the surrounding pavement before it dries. The bonding compound will begin to set up within approximately 15 minutes (at 70° F). Keep the exposed areas of Utilibond "wet" while carefully cleaning off the Utilibond from the surrounding surfaces. Thoroughly clean all mixing tools and pails before the bonding compound has a chance to set. Dip the whitewash brush in water and carefully apply moisture to the surface of the Utilibond in the kerf and center pilot hole, keeping it damp until it has set-up and the surface is firm to the touch.

10) Once the core has set and gained strength (30 minutes at 70° F), use water (high pressure is recommended) to clean off any excess debris and thoroughly sweep the area before leaving.

Properly dispose of all excess Utilibond material, and reuse or recycle the Utilibond pail.

Hot Weather Core Reinstatement Procedure

Utilibond™ is specially formulated for permanently replacing excavated cores in asphalt, asphalt and concrete and concrete road systems and sidewalks and other paved surfaces. The rapid hydration and fast strength gain of this product allows the roadway to be reopened within 30 minutes at 70°F/21°C.

However, sometimes cores will need to be reinstated when the ambient temperatures are well above 70° F.

Utilicor deems hot weather to be temperatures when the day time highs exceed 80 °F and extreme hot weather to be above100 °F. When reinstating cores in these hot or extreme hot weather temperatures certain procedures will help the crews attain a proper core reinstatement. Failure to follow these instructions may result in improper or poor reinstatements.

Utilibond™ permanent pavement bonding compound is designed to be mixed with a precise amount of water to the proportion of Utilibond powder. **This ratio must be maintained even in extreme hot weather conditions.** The precise amount of water required is one litre of water for one 22 lbs. bag of Utilibond powder. For a 44 lbs. bag of Utilibond powder, mix with 2 litres of water. Do not alter this ratio the ultimate strength gain and performance of the Utilibond™ will be reduced.

In the case of hot weather and extreme hot weather conditions the following tips will allow for additional working time during the process of reinstating the core:

- **Start with cold water to mix the Utilibond™ and keep the Utilibond™ in a cool place.** As only two litres of water are required for an entire 44 lbs. pail of Utilibond, filling a potable water container with cold tap water before leaving the yard and storing it in the air conditioned cab of a work truck on site until mixing is needed will help to inhibit the set up time of the Utilibond. Make sure the Utilibond powder is as cool as possible before mixing.

- **Reduce overall mixing time**. Utilicor suggests a full three minute mix time of Utilibond™ at 70°F. At this temperature this with help to accelerate the setting times for the product. However, in hot weather conditions we recommend reducing this time to 1½ minutes. Once the Utilibond™ is mixed through and is lump free, with a flow consistency of pancake batter, it is fine to stop the mixing process and start the core reinstatement.

- **Keep everything wet.** This would include the cored portion of the roadway and the core itself before reinstatement occurs. Dampen all portions of the cored roadway and core with a sponge just prior to reinstatement.

- **Once the core has been reinstated keep the kerf and pilot hole portions wet**. By using a wet soft bristled brush you can "paint" the top of the reinstated core with cold water – this will help the Utilibond™ to set a little slower and reduce any premature or rapid hydration of the Utilibond. Mke sure you keep the kerf and the pilot hole damp.

- **Keep the cores cool.** In extreme hot and sunny days the asphalt cores can literally "melt" if left unprotected at the side of the road with the sun beating down on them. An asphalt core will also have the tendency to expand, or "mushroom" due to excessive heat when left in the sun. We recommend storage of cores for short durations in the shade and if possible covered with wet burlap. For longer durations they should be carefully moved to an inside warehouse location.

- **Do not leave the core puller in the core for extended periods of time.** Once the core has been removed from the roadway it is imperative that the Utilicor puller be extracted from the center of the cut core. If it is left in the core in tightened position it could possibly cause the core to split. During reinstatement on a hot day only tighten the puller to the point that one can securely move the core.

With ambient temperatures of 70°F Utilibond has an initial set in 15 minutes, a final set at 20 minutes and is load bearing at 30 minutes, at which time the roadway can be safely reopened to traffic.

At correspondingly higher temperatures set times will be slightly reduced.

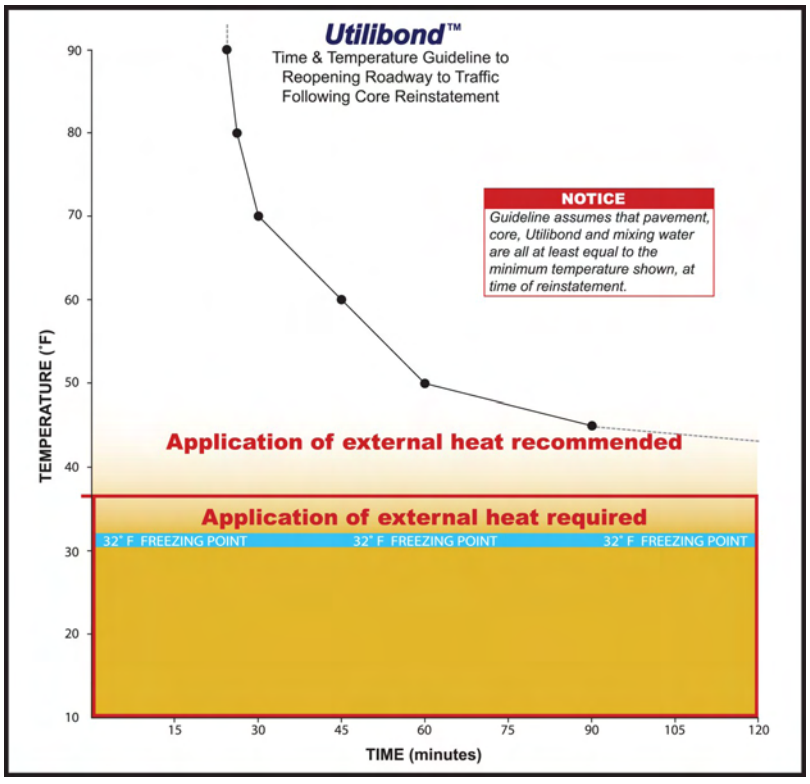
Time and Temperature Guide to Reopen Roadway to Traffic Using Utilibond Core Bonding Compound

Reinstatement at 70°F (21°F) - 30 Minutes to safely reopen the roadway to traffic
Cores may be safely reinstated with Utilibond and the roadway safely reopened to traffic in 30 minutes when the temperature of the pavement slab, core and bonding materials, including mixing water immediately before placement, are at a minimum of 70°F (21°C). At that temperature the bond strength of a typical 18-inch diameter core, 8-inches deep will be capable of supporting a wheel load of at least 30,000 lbs or 3 times the AASHTO H-25 Standard, in **30 minutes** after application, and the roadway can be safely reopened to traffic at that time.

Reinstatement at 50°F (10°F) - One hour to safely reopen the roadway to traffic
Cores may be safely reinstated with Utilibond and the roadway safely reopened to traffic in 60 minutes when the temperature of the pavement slab, core and bonding materials, including mixing water immediately before placement, are at a minimum of 50°F (10°C). At that temperature the bond strength of a typical 18-inch diameter core, 8-inches deep will be capable of supporting a wheel load of at least 30,000 lbs or 3 times the AASHTO H-25 Standard, in **one hour** after application, and the roadway can be safely reopened to traffic at that time.

Reinstatement at temperatures BELOW 50°F (10°C)
While reinstatement of cores can be performed with Utilibond at temperatures as low as 40°F (5°C) because of the proximity to freezing temperatures and the danger of frost crystals forming at the bonding interface, it is recommended that a source of external heat, such as a Utilicor Core Heater, be employed to raise the surface temperatures of both the core and the surrounding pavement to 70°F (21°C) at which temperature the bond strength of a typical 18-inch diameter core, 8-inches deep will be capable of supporting a wheel load of at least 30,000 lbs or 3 times the AASHTO H-25 Standard, in **30 minutes** after application, and the roadway can be safely reopened to traffic at that time.

Reinstatement at temperatures BELOW FREEZING - 32°F (0°C)
The Core Heating procedure can also be successfully employed to facilitate core reinstatement with Utilibond at temperatures **below freezing,** providing that the duration and application of external heat from an approved Core Heater is sufficient to raise the temperature of both the core and the surrounding pavement to approximately 70°F (21°C) and the bonding materials, including water, immediately before placement , are at the same minimum temperature of 70°F (21°C)



As might be anticipated, the duration of heating required to achieve these results at below freezing temperatures, using an approved core heater, will vary inversely with the ambient temperature of the pavement but should not exceed 15-20 minutes in normal circumstances at a temperature down to 10°F (-21°C).

Once the surface temperature of the core and the pavement reach a sustainable 70°F (21°C), normal core reinstatement procedures can be employed and the bond strength of a typical 18-inch diameter core, 8-inches deep will be capable of supporting a wheel load of at least 30,000 lbs or 3 times the AASHTO H-25 Standard, in **30 minutes** after application, and the roadway can be safely reopened to traffic at that time.

Cold Weather Core Heater Reinstatement Procedure

The Utilicor Core Heater **should be used** when ambient temperature drop below 50°F. as set up times will exceed the 30 minute target. The Core heater **must be used** when ambient temperatures are below 32° F.

Before you begin, make sure the core is dry fitted properly, as per warm weather reinstatement.

Place the core heater base in the hole and connect heater-blower to unit and place core on the base.

Place core cover on top of the Base, and open vents on top of core cover - ignite blower and position into baffle.

Check the temperature occasionally with a non-contact infrared temperature sensor.

When the surfaces of the core reaches at least 70° F, the core reinstatement process can begin. Note: Make sure the Utilibond powder is stored in a warm location, and use warm water to mix with.

Remove the core heater and place the core in the opening, which will keep the core warm while mixing the Utilibond. Once ready, remove core, pour in mixed Utilibond, and reinstate the core as per normal procedure.

The reinstated core will begin to set up within 15-20 minutes. Take intermittent temperature readings to better gauge set time.

At 70° F ambient temperatures Utilibond will reach final strength gain in 30 minutes.

Final core reinstated.

Valve Box / Test Station Installation

1) Core hole through pavement around existing valve box or location of test station.

2) Clean up area. Remove core with core puller or sunken valve box by hand.

3) After test wire is installed and hole is back filled clean the sides of the cored hole.

4) Add 1-2 inches of pea stone and install test box or new valve box

5) Using a straight edge, make sure the top of the valve box is flush with the surrounding pavement.

6) Test box or valve box is flush and ready for reinstatement.

7) Supplies required: Utilibond, water, pea stone, trowels, sponge, whitewash brush, power drill and Utilibond mixing blade.

8) Add one litre of water to the pail. (for larger areas mix both bags of Utilibond)

9) Add bag of Utilibond powder to pail while mixing blade is engaged.

10) Mix for 2 minutes or until Utilibond is smooth and flowing.

11) Add 3 litres (3 full cups) of ¼ to ½ inch pea stone to the Utilibond, mix until blended together. (2/3 Utilibond to 1/3 pea stone)

12) Spray outside of cored hole and test box with Utilicure. Carefully pour Utilibond mixture into the hole around the valve box.

13) Consolidate the mixture into the hole to make sure there are no voids.

14) Smooth and remove excess Utlibond. Trowel smooth.

15) Keep surface wet with whitewash brush to ensure proper hydration. Spray top liberally with Utilicure while setting.

16) Spray top portion liberally with Utilicure.
30 minutes @70°F the roadway may be safely reopened to traffic.

Delaminated Cores

Once a core has been cut, and depending on the road which it was cut from, it is not uncommon to find the core has come apart horizontally in sections… or delaminated.

This occurs most often when the top portion of the core is asphalt and the bottom section is concrete. However, often a road which has been milled and overlaid with a new layer of asphalt rolled over the older roadway, the binder used to glue the new with the old will not have adhered properly, and once the core is cut and extracted the two sections will delaminate.

By inserting the core puller all the way to the bottom of the core it is possible to remove both delaminated sections. It is also possible to use Utilibond to bond the delaminated sections together when reinstating the core.

Above: The core has been extracted from the roadway, but in two pieces.
This core has delaminated.

To reinstate horizontally delaminated cores:

1) Dry fit the core 1/2" lower than normal.
2) Make sure the orientation of the top portion matches the bottom portion.
3) Mark with paint if required.
4) Reinstate the bottom portion first, allowing the Utilibond to flow up and on to the top of the lower core - pour more Utilibond on top of bottom core.
5) Slowly lower the top portion onto the bottom portion and push down to level with surrounding roadway.
6) Clean up remaining Utilibond off top of roadway and core and trowel smooth.
7) Keep kerf and center pilot bit area wet with wash brush and clean water until initial set has occurred.

Core Farms

It is also not uncommon to see the core that has been cut and extracted from the road completely fall apart, and not be suitable for reinstatement.

In these cases it is possible to import a core from either another piece of roadway which is destined to be a trench or an area where a larger excavation is to be performed. In this case simply have the coring equipment cut, remove and store spare cores before actual trench or the excavation performed.

In some instances an actual "core farm" can be built where the coring crews can pre-cut cores that match the optimal core composition and thickness. Typically these "core farms" are constructed with the same asphalt specifications that the municipality requires in their new road construction specifications and is of a similar depth profile.

As seen above, a Core Farm where cores can be harvested year around as needed to replace defective cores from the field.

Overlapping Cores

The industry standard size for keyhole is 18" in diameter. However often larger or smaller cored opening are required due to differing applications. While spot locates for direction drilling facility verification can be as small as 12", it is important to remember that when the core will be reinstated there really is little to be gained by making the hole smaller than is practical for the work to be preformed.

Often there is a need to core a larger diameter hole than the standard 18" diameter. All Utilicor equipment can accommodate coring drum diameters up to 24", and a combination of these larger cored openings may even be capable of serving as a launch pits for HDD.

While not the norm, and usually due to a missed locate, it is possible to core and properly reinstate overlapping cores.

Two 18" diameter cores are cut to allow for greater access to buried facility

Two cores that have been simultaneously reinstated

As seen above, a triple core cut, extracted, and reinstated as one repair

Utilibond Colors to Match Existing Roadways

Utilibond comes in two colors - Aged Asphalt and Natural Concrete. Aged Asphalt Utilibond is identical in composition to Natural Concrete Utilibond with the exception of a carbon black additive, which once cured will dry to a darker color than Natural Concrete Utilibond. The Natural Concrete coloured Utilibond once dried will closely match that of a typical concrete sidewalk or concrete topped roadway.

Older roadways, which are asphalt topped, have the appearance of being lightened in shade when compared to that of a newly constructed asphalt roadway. In these cases Aged Asphalt Utilibond will closely match that of am asphalt roadway which has been in use for some years. However, on newly constructed asphalt topped roadways Utilibond can be mixed to appear even darker with the addition of carbon black - which is provided in the form of UtiliBlack.

The 2 oz. container of UtiliBlack can be added to either the Aged Asphalt formulation or the Natural Concrete. Follow the directions below.

1) Prepare the bonding compound by first removing the bag (s) of Utilibond from the pail. Add water to the level indicted on the outside of the pail. Do not exceed or reduce the amount of water. Proportions of water to Utilibond are crucial for effective performance. Use the 1-litre container supplied in all Twin Pack pails to achieve exact water proportions.

2) Carefully open the bag(s) of Utilibond, creating a clean opening to pour the Utilibond powder from. With the mixing blade inserted into the bottom of the pail, slowly add the Utilibond powder to the water in the pail, while engaging the drill with the mixing blade.

3) Using a handheld drill and appropriate mixing blade, mix the bonding compound until it is smooth and flowing. (Mixing time is approximately 2-3 minutes). Once mixed the Utilibond will appear smooth and creamy with a flow characteristic similar to that of pancake batter. Do not add additional water if the mixture looks dry at the beginning of the mixing process. Keep mixing and the Utilibond compound will "turn" after about one minute and begin smoothing out.

4) Add Utiliblack to Utilibond mixture. Continue mixing until carbon black is mixed through and proper shade has been achieved. It is important to note that unlike Aged Asphalt Utilibond, Utilibond with Utiliblack added will not lighten as it cures. The color seen in the pail while mixing will be the color of the Utilibond once set.

Adjusting Aged Asphalt to a Lighter Shade

If the roadway is Asphalt topped and quite old, it may be necessary to lighten the Aged Asphalt colored Utilibond.

There are two options available to achieve a lightened Aged Asphalt:
1) Mix one bag of Natural Concrete with one bag of Aged Asphalt.
2) Once the core has been reinstated continually keep the kerf and center pilot hole area wet with water. This will have the effect of washing out some of the carbon black in the Utilibond, and once set it will appear lighter in color.

Core Drum Rotation Speed
The rule of thumb here is the smaller the drum diameter the faster the rotation, and the larger the drum diameter the slower the rotation. If a drum rotates too fast for its diameter, the diamond segments will be a "glazed", or polished, and new diamonds will cease to be exposed. As a result the cut will take too long. Running at too slow a speed will result in premature erosion of the diamond segments and will reduce the cuting life of the segments, and result in a higher cost per cut.

Below are some general guidelines for setting the drums R.P.M. to get you the best penetration rate and the longest core drum life.

•12" drum: 200 rpm to 250 rpm •18" drum: 190 rpm to 230 rpm •24" drum: 160 rpm to 200 rpm

Coring Drum Segments
Coring drum segments are composed of synthetic diamonds impregnated in a specially formulated matrix. As the bit is driven into the substrate the diamonds grind away the material being cut. In the keyhole environment we are generally cutting through two very different materials: asphalt and concrete. The asphalt cutting creates slurry that is very abrasive, and contrary to conventional wisdom, even though asphalt is a softer material than concrete, it is more abrasive on the segments than when cutting through concrete.

Utilicor, through years of in-field testing, has developed a segment that provides its end users with the best of both worlds. Our ProCor coring drums are equipped to handle both asphalt and concrete and will provide quick and efficient core cutting action with extended drum life. This means more cuts per drum and reduced cost per core cut.

Feed and Speed
Feed and speed are the two variables the core cutter has to keep in mind when cutting a core. The correct down pressure feed rate will depend on what you are cutting through. With this in mind, all of Utilicor's equipment comes with a feed gauge and a rotational pressure gauge. We recommend a down pressure of 500-700 psi and a rotational back pressure of 800-1200 psi. This should result in a penetration rate of approximately one inch per minute, through asphalt, concrete or composite roadways and sidewalks. If you are taking longer than this, one or more parts of your cutting equation need to be adjusted.

Water for drum cooling slurry removal
While there are core drums designed to "cut dry", in the keyhole process we recommend always using water to cool and lubricate the drum and to carry away the slurry away that is created in coring. Water also keeps the dust down. How much water is proper amount? We recommend a ratio of approximately one gallon per one inch of core cutting. Too much water will clear away all the slurry too quickly, and it's that slurry that helps to expose the new diamonds in the segment during the coring process. Too little water will result in a thick slurry that might cause the core to get stuck inside the core barrel. You should adjust your water flow to keep the kerf area clear, but not so much that you flood the street. As a rule of thumb, for a 10" thick core, you should normally use about 10 gallons of water.

Coring Completion
When you are coring it is impossible to "see" when you are through the roadway or sidewalk. But there are a number of ways that will help you to determine when to stop cutting. If you core too far below the paved surface there is a danger that the loose dirt will work its way up into the drum and cause the core to become stuck. We have five senses, and when you use them they will tell you when it's time to stop coring and time to check to see if your core is ready to be extracted.

Sound
The Utilicor core cutting process incorporates a center pilot bit which simultaneously cuts a center pilot hole through the center of the core. This pilot bit extends an inch or two beyond the bottom of the core barrel so it will actually cut through the pavement before the rest of the drum. When that occurs, you can usually hear a change in the coring sound, and you will know that the bottom of the coring drum needs only to cut another inch or so.

Sight
Watch the color of the slurry. The slurry from the cutting of asphalt or concrete is a distinct and consistent color. As soon as the core drum cuts through the bottom of the roadway or sidewalk, the slurry coming up to the surface will look different. Watch for the change in color of the slurry, and it will help you tell when you are through. Also, watch the Hydraulic gauge that measures pressure on the coring drum. It will often spike just as the core drum cuts through the last portion of the core. When you see this spike in PSI you will know you are through and the core can be extracted.

Feel
All Utilicor coring equipment is equipped with a proportional orbital feed system connected to the steering wheel that gives the operator real time feedback from the coring operation. As you cut through different materials you will notice a different feel. Once the drum penetrates through the asphalt or concrete and into the soil beneath the pavement, the steering wheel will become easier to turn, and you will know that you are through. To check that the core is ready for extraction, stop coring, lift the drum, and stick a pry bar down the center pilot hole in the middle of the core and gently try to rock it back and forth. If it moves easily you will know that the cut is all the way through. This action will also help to break the suction between the bottom of the core and the base of the roadway.

Extracting the Core
Cores are heavy. And larger diameter and deeper cores are very heavy. Always use caution when extracting these from the roadway. Utilicor's specially designed core puller is the safest way in the industry to extract a core. The rubber stopper at the bottom will expand inside the pilot hole and the friction will create a solid hold on the core. A 5 foot pry bar can be inserted through the eye-bolt mounted on the top of the core puller and with a crew member on either side of the core the two of you can share the load and safely lift the core out of the hole. Make sure you lift with your legs - and never with your back. For cores too heavy for two crew members to lift, use the core hoist on the unit or hook the core puller to a small skid steer or backhoe and lift.

Storing and Moving the Core
Cores are circular, and when turned on their side they roll. This helps when you need to move one from the middle of the road to the side of the road. Gently tip it on its side, and roll it away. If you need to store the core for an extended period of time, and it is a hot day, store it upside down on a flat surface. Because of the way it is poured in the first place, the bottom of the core is usually uneven. On a hot day, if you rest the core on this uneven bottom, the asphalt is likely to soften allowing the core to sag or deform.

Delaminated Cores
Not every core cut will be perfect. Many older roadways have been overlaid (resurfaced) with new layers of asphalt. Sometimes entire new roadways are laid over old roadways. Every time you core it's a bit of a crap shoot as to what you will find. Sometimes a core will have separated between its different layers of asphalt or between the asphalt the concrete. Make sure that you insert the core puller all the way down to the bottom so that you can pull the core (and all of its layers) out in one piece. When you seek to reinstate this delaminated core, the bond strength of Utilibond will effectively bond the layers together.

Marking Cores for Reinstatement
Because you will be saving the core to be reinstated at a later time, it is important to mark its orientation in the roadway before you core cut and extract it. We recommend using white marking paint with two intersecting lines that will extend across the cutline of the kerf of the core. The letter V works best, as there is only one way to put it back to make the lines match up. This is preferable to an X, which due to being symmetrical can result in misinterpretation of its original orientation.

In areas when you will be cutting multiple cores, paint a number on the top of the core and mark the roadway with the same number. Reinstatement is simplified when you know which core goes in which location.

DESCRIPTION

Utilibond^{TM} is a ready-to-use, fast setting, high strength waterproof bonding agent. It is non-metallic, non-staining, and non-toxic. ***Utilibond***^{TM} is specially formulated to be used for permanently reinstating pavement cores. It comes in two colors: Aged Asphalt and Natural Concrete.

WHERE TO USE

Utilibond^{TM} is specially formulated for permanently replacing excavated cores in asphalt, asphalt and concrete, and concrete road systems and sidewalks and other paved surfaces. The rapid hydration and fast strength gain of this product allows the roadway to be reopened within 30 minutes at 70°F/21°C.

BENEFITS

Fast setting
High strength
Forms waterproof bond
Excellent freeze-thaw resistance
Very low permeability
High resistance to sulphate attack
Non-toxic
Chloride free

PROPERTIES

Compressive Strength @ 70°F (21°C)

(ASTM C109-77)
Mixture Consistency
0.53 US gal water/44 lb (2 L water/20 kg bag)

1 hour	1,640 psi (11.3 Mpa)
2 hours	2,459 psi (17.0 Mpa)
24 hours	6,344 psi (43.8 Mpa)
4 days	7,659 psi (52.8 Mpa)
7 days	8,600 psi (59.3 Mpa)
28 days	9,500 psi (65.5 Mpa)

Slant Shear Bond Strength @ 70°F (21°C)

(ASTM C882-91)
0.53 US gal water/44 lb (2 L water/20 kg bag)

30 minutes	231 psi (1.6 Mpa)
45 minutes	422 psi (2.9 Mpa)
1 hours	670 psi (4.6 Mpa)
2 hours	836 psi (5.8 Mpa)
4 hours	1182 psi (8.2 Mpa)

Punch Through Bond Strength @ 70°F/21°C

0.53 US gal water/44 lb (2 L water/20 kg bag)

30 minutes	137.0 psi (0.9 Mpa)
45 minutes	186.9 psi (1.3 Mpa)
1 hour	281.5 psi (1.9 Mpa)
2 hours	288.3 psi (2.0 Mpa)
4 hours	322.0 psi (2.2 Mpa)

Punch Through Bond Strength @ 70°F/21°C

Compared to AASHTO H-25 Highway Load
Factor of Safety 10,000 lbs (4536 kg) per tire
0.53 US gal water/44 lb (2 L water/20 kg bag)

30 minutes	5.2 Times
45 minutes	6.6 Times
1 hour	9.9 Times
2 hours	10.2 Times
4 hours	11.4 Times

Length Change (Shrinkage)

(ASTM C157-91) % Shrinkage

1 day	0.04%
3 day	0.05%
28 days	0.06%

Chloride Permeability @ 73°F (23°C)

(AASHTO T-277-831)
0.53 US gal water/44 lb (2 L water/20 kg bag)
208 Coulombs

Water Absorption

(M1-67-92) % Weight Gain
0.53 US gal water/44 lb (2 L water/20 kg bag)
3.67%

Salt Scaling

(MTC Method 1315-07)

50 cycles	0.467 kg/m²

The above information is representative of actual production runs. Independent test results may vary from the above by approximately ± 10 %.

PREPARATION
Remove all loose dirt and particulate from the cut surface. Wipe the cut surface of the core and substrate with a clean damp cloth. To achieve maximum bridging strength the core should be bedded on a one inch layer of clean 10mm (3/8") pea gravel.

MIXING
For optimum strength ***Utilibond™*** should be mixed with .53 US gallon (2 L) of clean water to 44 lbs (20 kg) bag. Open the ***Utilibond™*** pail. Remove the bag of ***Utilibond™*** from the pail. Add 0.53 US gallon (2 L) of clean water to the pail. Add the Utilibond mixture to the water in the pail while mixing. Mix for 3 minutes until you have a smooth consistent mixture with no lumps. (For best results use a universal power mixer).

CURING
Utilibond™ will begin to cure in less than 15 minutes @ 70° F/21°C. Be sure all surface areas are properly prepared before mixing.

LIMITATIONS
Not recommended for use on substrates below 32°F (0°C) (see cold weather procedures).
Not recommended for structural bonding applications.
Not suitable for acid exposure.
Maximum service temperature 350°F (176°C).
Minimum kerf thickness 3/8" 9.5mm.

COVERAGE
Up to an 18" diameter by 22" deep core replacement per 44lb (20 kg) bag.

STANDARDS
Approved for use in reinstatement of pavement cores.

PACKAGING
Utilibond™ is packaged in 44lb (20 kg) multi- wall bags in a 5 US gallon (18.9 L) sealed polyethylene pail.

CLEAN UP
Clean all mixers and tools with water before product hardens.

STORAGE
May be stored short term anywhere as long as the product is kept dry. Dry, heated warehouse storage is recommended for extended storage.

SHELF LIFE
Two year shelf life when stored in original packaging. If stored outside, polyethylene pails should be covered or protected from extensive exposure to sunlight or UV rays.

SAFETY PRECAUTIONS
Consult Material Safety Data Sheet (M.S.D.S.) for specific instructions. MSDS # 216.

WARRANTY
The recommendations made and the information herein are based on our own laboratory and field experience, and are believed to be accurate under controlled conditions. However, no warranty or guarantee of accuracy is made because we cannot cover, nor anticipate, every variation encountered in weather and job-conditions, methods used and types of substrates to which the product is applied. The users should make their own tests to determine the suitability of this product for their purposes *Utilicor™* makes no other warranty, express or implied, and hereby expressly disclaims a warranty of merchantability or fitness for a particular purpose.

The liability of *Utilicor™* shall be limited in all events to supplying sufficient product to re-treat and/or repair the specific reinstatement for which *Utilibond™* product has been used. *Utilicor™* reserves the right to have the true cause of any difficulty or failure determined by accepted test methods. *Utilicor™* shall have no other liability, including liability for incidental, consequential or resultant damages, however caused, whether due to breach of warranty, negligence, or strict liability.

THIS WARRANTY MAY NOT BE MODIFIED OR EXTENDED BY REPRESENTATIVES OF *Utilicor ™*, ITS DISTRIBUTORS OR DEALERS.

MATERIAL SAFETY DATA SHEET

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SECTION I - PRODUCT IDENTIFICATION

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Product name: UTILIBOND
Product use: Non-shrink bonding compound for use in permanently replacing pavement cores.
Supplier name and address: Manufacturer name and address:
UTILICOR TECHNOLOGIES INC. Refer to Supplier.
49 Sheffield Street
Toronto, ON, Canada
M6M 3E5
Emergency Tel.#: 888-572-6666
WHMIS CLASS: D2A *(Chronic health, Carcinogenicity)***, E** *(Corrosive properties)***.**

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SECTION II - INGREDIENTS

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LC50 / 4 Hrs LD50 mg/kg
Ingredients CAS# wt.% (Rat, ihl.) (Rat, oral) (Rabbit, dermal)
Silica sand 14808-60-7 40 - 70 N/Av N/Av N/Av
Portland cement 65997-15-1 30 - 60 N/Av N/Av N/Av
Carbon black 1333-86-4 0.1 - 1 6750 mg/m3
>15,400 >3000

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SECTION III - PHYSICAL DATA

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Physical state, odour and appearance: Charcoal grey powder, no odour. **Odour threshold:** N/Av
Solubility in water: <10%. **Specific gravity:** 2.2
Coefficient of water/oil distribution: N/Av **Vapour pressure (PSIG):** N/Av
Boiling point: N/Av **Freezing point:** N/Av
pH: 12.5 (aqueous solution) **Vapour density (Air = 1):** N/Av
Evaporation rate (BuAe = 1): N/Av **Volatiles (% by weight):** N/Av

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SECTION IV - FIRE AND EXPLOSION DATA

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Conditions of flammability: Not considered flammable.
Flash point (Method): N/Ap **Auto-ignition temperature:** N/Av
Upper flammable limit %: N/Ap **Lower flammable limit %:** N/Ap
Means of extinction: Use media suitable for the surrounding fire, such as dry chemical, foam, carbon dioxide.
Sensitivity to mechanical impact/static discharge: N/Av.
Special fire fighting procedures: Firefighters should wear proper full chemically protective equipment and self-contained breathing apparatus. Move containers from fire area if it can be done without risk. Water spray may only be useful in cooling equipment exposed to heat and flame.
Unusual fire and explosion hazards: Product becomes alkaline on contact with moisture.
Hazardous combustion products: Carbon oxides.

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SECTION V - REACTIVITY DATA

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Stability: Stable under the recommended storage and handling conditions prescribed. Product becomes alkaline on contact with moisture. Hazardous polymerization will not occur.
Incompatible materials: Water, oxidizing agents, acids.
Conditions of reactivity: Keep away from moisture until product is used. Stable under ambient pressure and temperature.
Hazardous decomposition products: None known. Refer to Section IV for 'Hazardous combustion products'.

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SECTION VI - TOXICOLOGICAL PROPERTIES

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******Routes of exposure and acute effects******
Exposure limit: ACGIH-TLV: Silica, crystalline – 0.05 mg/m3; Portland cement – 10 mg/m3; Carbon black – 3.5 mg/m3.
OSHA-PEL: Silica, crystalline – 10 mg/m3 *(respirable)*; Portland cement – 15 mg/m3 *(total dust)*;
Carbon black – 3.5 mg/m3.
Inhalation: Harmful if inhaled. Inhalation of dusts causes irritation to the nose, throat and respiratory tract. Symptoms may include coughing and inflammation of nasal tissues.
Skin: Short term exposure to dry dusts may cause mild irritation. Longer exposures or contact with wet product could cause severe irritation and/or chemical burns. Burns may be delayed.
Eyes: Direct eye contact may cause mild to severe irritation. Could cause chemical burns and eye damage if not promptly removed.

SECTION VI - TOXICOLOGICAL PROPERTIES CONTINUED

Ingestion: May be harmful if swallowed. May cause irritation to mouth, throat and stomach.
Chronic effects: Prolonged or repeated inhalation may cause severe, irreversible scarring of lung tissue (silicosis). Prolonged or repeated skin contact may cause severe dermatitis (drying and cracking).
Carcinogenicity: Contains Crystalline silica. Crystalline silica is classified as carcinogenic to humans by IARC (Group 1) and ACGIH (Group A2). Contains Carbon black. Carbon black is classified as possibly carcinogenic to humans by IARC (Group 2B).
Reproductive effects, Teratogenicity, Mutagenicity: Contains Carbon black. Carbon black may cause mutagenic effects to nonreproductive cells, based on animal evidence.
Sensitization to material: None known. Synergistic materials: N/Av.
Conditions aggravated by exposure: Pre-existing skin, eye and respiratory disorders.

SECTION VII - FIRST AID

Inhalation: Immediately remove victim to fresh air. Obtain medical attention if irritation persists.
Skin: Immediately flush skin with soap and water, while removing contaminated clothing. Obtain medical attention. Launder clothing before re-use.
Eyes: Immediately flush eyes with water for at least 20 minutes. Obtain medical attention immediately.
Ingestion: Do not induce vomiting. Obtain medical attention.

SECTION VIII - PREVENTIVE MEASURES

Spill, leak or release: Wear appropriate protective equipment for dusty conditions. Ventilate area of release. Stop leak if you can do so without risk. Sweep up or vacuum spilled material using a method that does not generate airborne dust. A dust retarding floor-sweeping compound may be used. Place contaminated, spilled material into a dry container for later disposal (see below). Notify the appropriate authorities as required.
Waste disposal: Handle according to recommendations listed below. Dispose in accordance with all applicable government regulations.
***** PROTECTIVE EQUIPMENT *****
Respiratory protection: For prolonged exposure or if the TLV is exceeded, wear NIOSH-approved dust respirators.
Ventilation: Use in well ventilated area. Use general or local exhaust ventilation if the TLV is exceeded or is not known.
Protective gloves: Effects on the skin may be delayed. Gloves impervious to the material, such as Neoprene or PVC, must be worn during handling. Advice should be sought from glove suppliers.
Eye protection: Wear safety glasses with side shields or goggles to prevent any dusts from entering the eyes.
Other protective equipment: An eyewash station and safety shower should be made available in the immediate working area.
***** STORAGE & HANDLING *****
Storage and handling conditions: Handling: Wear protective equipment for dusty conditions during handling. Use in a well ventilated area. Avoid inhaling dusts. Avoid all contact with eyes, skin and clothing. Keep away from acids and incompatibles. Keep away from moisture until product is used. Keep container tightly closed when not in use. Wash thoroughly after handling. Storage: Store in a cool, dry, well-ventilated area away from incompatibles. Do not allow product to get wet, as it becomes alkaline and will eventually harden. May be stored off the ground and under waterproof tarp if stored outdoors.
Special Shipping Information: Transportation of Dangerous Goods Clear Language Regulations (CLR): Not regulated for transport.

Additional notes or references:
Abbreviation: N/Av: not available N/Ap: not applicable TLV: Threshold Limit Values
PEL: Permissible Exposure Limit
IARC: International Agency for Research on Cancer
NIOSH: National Institute of Occupational Safety and Health
CAS: Chemical Abstract Services
ACGIH: American Conference of Governmental Industrial Hygienists
OSHA: Occupational Safety and Health Administration
Reference: 1. ACGIH, Threshold Limit Values and Biological Exposure Indices for 2002.
2. International Agency for Research on Cancer Monographs, Supplement 7, 1988.
3. Canadian Centre for Occupational Health and Safety, CCInfoWeb databases, 2003 (Chempendium and RTECs).
4. Material Safety Data Sheet from manufacturer.

SECTION IX - PREPARATION INFORMATION

Prepared by: UTILICOR TECHNOLOGIES INC.
Telephone No. 416-391-3901
Preparation date: February 3, 2011

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