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# POTHOLING WITHOUT POTHOLES:
# A CORE STRATEGY FOR UTILITY CUT REPAIRS

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**ABSTRACT**: This paper discusses keyhole technology and the coring and reinstatement process that, like microsurgery in the medical field, enables utility crews to cost-effectively locate underground infrastructure or perform repair or maintenance work on underground pipe or other buried plant from the road surface through an 18-inch diameter “keyhole” cored through the pavement thereby avoiding more costly, disruptive and inherently more dangerous excavation methods. Most importantly it results in a permanent, almost invisible, perfectly matching, waterproof pavement repair that can actually extend the performance life of asphalt and concrete pavements and significantly reduce traffic delays and inconvenience to the public as a result of roadwork in the Right of Way.

Not only are keyholes smaller than conventional utility cuts but they are less destructive of the pavement as a load bearing system and will not sink, allow infiltration of ground water or become potholes. There is no noise or vibration from jack hammers or pavement breakers used in conventional utility cuts to disturb the neighbors or damage the surrounding pavement and roadbed. According to independent testing the bonded core has sufficient strength to support the combined weight of five transit buses (50,000 lbs.) – five times the AASHTO H-25 standard -- and allows the road to be reopened to traffic within 30 minutes of the repair. It is a reliable, field-proven process with ZERO reported failures in more than 15 years and over 50,000 successful corings and reinstatements in tough urban climates nationwide.

It is also an environmentally sensitive technology that gets full marks for reducing the need for new paving materials and the disposal of old, by reusing the same materials that were used to build the roadway to repair it after excavation.

Keyhole coring and pavement reinstatement has a major application in cost-effectively locating and verifying buried utilities before installation of new infrastructure is undertaken, and is one of the key methods of avoiding cross-bores in sewer pipes.

## Introduction

Providing and maintaining a smooth and safe riding surface on roads and streets is a major challenge for highway agencies and municipal transportation officials, particularly when the roadway is the main corridor for utilities, and when utility cuts, needed to access and repair underground infrastructure, are poorly repaired afterward.

Utility cuts are made in pavement to install and repair gas, communications, water, and wastewater infrastructure. They are also made to locate potential conflicts when doing horizontal directional drilling or to map existing infrastructure during subsurface utility engineering (SUE). This is called “potholing” or “daylighting” in which the underground utility is exposed by vacuum excavation through a small hole cut through the pavement. Once the work has been completed, if the repair is not done properly, the repaired pavement will settle relative to the original pavement or crack and allow ground water to penetrate into the subgrade. It is this groundwater that is the most common cause of pavement failures and potholes. If the repair is done properly, no groundwater penetrates and we have a situation, as the title of this paper suggests, where we have “potholing *without potholes*”.

How you make the pavement cut is also important. Jackhammers and backhoes not only disturb the original pavement, but the base course and subgrade soils around and below the cut to a distance of 2 to 3-feet beyond the limits of the actual trench. This additional area is termed the “zone of influence”.

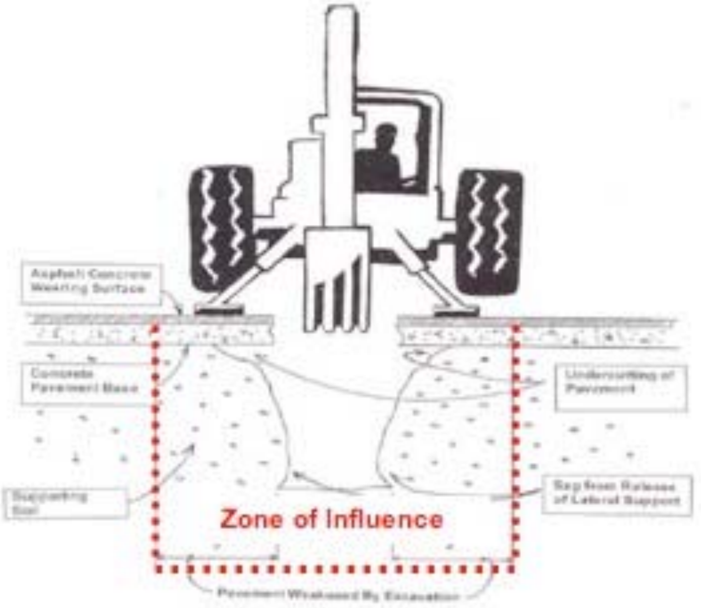

***Figure 1:*** Zone of influence is the area around the excavation that is susceptible to slippage or collapse resulting from external surface load, from vehicles, plant, or excavated material at or near the excavation. [Original illustration © University of Iowa [1]]

Research conducted by the National Research Council of Canada and the Region of Ottawa-Carleton[2] found that improperly restored utility cuts can reduce the pavement life by up to 50 percent and have a cost impact of from $4.32 per square metre for pavements resurfaced more than 10 years prior to the trenching, to as much as $23.78 per square metre for pavements that were resurfaced less than 2 years before.

Because it is considered to be in the public interest for utilities to use the right-of-way of public roads and streets, when it does not interfere with the primary highway purpose, municipalities cannot arbitrarily prohibit utilities from installing or gaining access to their buried plant, even under newly constructed, repaved or “protected” streets.

### Utility Cut Permits and Restoration Procedures

While they cannot prohibit access, municipalities can, and do, seek to impose conditions on access in their utility cut permits that will allow them to recover reasonable administrative costs and compensation for actual or future damage, and to prescribe conditions and specify processes for repair and restoration.

But a regime of fees and arbitrary procedures may not be the best answer. Rather than simply increasing street cut fees that they charge for presumptive pavement damage caused by utility cuts, or requiring slurry treatment or costly mill and overlay of all utility cuts, municipalities need to be more selective in the use of this powerful regulatory device. The result could be a situation in which the municipalities and their citizens would wind up with a cleaner environment, a better performing road system and reduced traffic congestion and delay. And all of this begins with the pavement cut permit.

Last year, an estimated 3.6 million pavement cut permits were issued at the municipal level across North America to facilitate the repair or installation of infrastructure, or to conduct SUE work in planning future infrastructure work. While these permits also cover extensive trenching and other large open pit projects, it is estimated that between 20-25%, or approximately 800,000, are of the smaller utility cut variety in respect of work that could be performed through an opening no larger than 2-feet by 2-feet or 2-feet by 3-feet in area.

These cuts may start out to be small, but by the time you apply the mandatory one or two foot T-section cut-backs required in many jurisdictions when permanently repaving or restoring the road surface, you've increased the size of the paving restoration (and disposal requirements) from 4 to 6 square feet to an area of 20 to 42 square feet of asphalt – 8 to 10-inches deep. That's between one to two-and-one-half tons of old paving materials that needs to be disposed of, and an equal amount of new paving materials brought in to repair the road. Applied against the number of utility cuts of this size permitted each year, that would amount to almost two million tons of hot-mix asphalt (HMA) and an equivalent amount of spoil that had to be trucked away. That's enough hot-mix asphalt to resurface 20,000 miles of four-lane highway and enough spoil to cover 10 football fields with asphalt spoil 50-feet deep – *every year.*

Spurred on by the spiraling cost of petroleum-based pavement products that consume vast amounts of energy to produce, and emit large quantities of greenhouse gases in their production and transportation, momentum is building for sustainable solutions that encourage more environmentally friendly technologies in transportation infrastructure construction and maintenance. These technologies can reduce the consumption of new paving materials and the disposal of old materials, and can directly re-use and recycle existing materials in the repair and maintenance of our road systems. One of these environmentally friendly technologies is keyhole coring and reinstatement.

### Keyhole Technology

Emulating a procedure practiced by laparoscopic surgeons for years, keyhole technology is a process of excavating a small, precisely controlled, hole in the right-of-way to allow utilities to gain access to their buried infrastructure and repair it more safely from the surface using long-handled tools. It can also be used to identify the exact location of buried utilities to avoid damaging them during horizontal directional drilling or boring, and as part of SUE in the planning and design stages of highway construction. Vacuum excavation is used to remove the soil to expose the buried plant.

***Figure 2:*** (Left) Rotary coring unit cores 18-inch diameter core; (Center) Core is removed and set aside. Vacuum excavation (not shown) is used to expose the infrastructure; (Right) After the work has been completed, the core is replaced and bonded back into the pavement as a permanent repair.

More recently, as shown in Figure 2, to facilitate vacuum excavation and location of infrastructure that is buried under paved surfaces, a rotary coring device has been adapted to core a small, up to 18-inch diameter, hole through the pavement. The core or coupon of pavement is extracted and set aside to allow vacuum excavation to expose the underground plant. After the underground work has been completed and the hole backfilled to the base of the pavement, the same core of pavement that was removed earlier can now be bonded back into the roadway with a special bonding agent as a permanent repair. No pavement spoil is created, no new paving materials are required to repair the road surface, and the road can be safely reopened to traffic again within 30 minutes of the repair, thus reducing traffic congestion and public inconvenience.

Not only can the road be reopened sooner after the original excavation – at least an hour sooner than with conventional restoration methods – but, because the initial keyhole repair is "permanent", there is no need to subsequently shut down traffic again for two to three more hours for permanent pavement repairs. This can mean an average reduction in road closing duration from three to four hours which, if extended nationwide to each of the approximately 800,000 small hole utility cuts performed in our streets every year, can have a major impact on local traffic and the environment.

For example, if the process had been used in all of those 800,000 cases where it was practical to do so, work-zone congestion could have been reduced nationwide by almost 2.8 million hours of delay and would have meant savings of more than 1.9 million gallons of otherwise wasted fuel. Add to that the reduction in consumption and disposal of paving materials and reduced pollution levels associated with the evaporation of volatile organic compounds from new-laid pavement, and you have a prescription for both huge economic savings and significantly reduced environmental impact.

### Better Pavement Repair

The coring and reinstatement process also results in a better pavement repair, less damage to the remaining roadway and a waterproof mechanical joint that restores the road to the load sharing capability that existed prior to the excavation. It also eliminates the potential for ground water penetration that is the major cause of potholes.

Attempts to use tack-coats or crack-sealants to create a waterproof, permanent joint between new asphalt and the original paved surface, have limited success. Unlike bonding materials specifically designed for the process, like *Utilibond*™, that have high levels of adhesive and cohesive strength that can actually create a mechanical joint between the two surfaces, these tack-coats and sealants, as well as other common grouting materials, fail because there is virtually no adhesive or cohesive strength in the materials. As their names suggest, they are a "sealant" or "grout" that fills the void between the two surfaces – *but only as long as they remain in place undisturbed.*

But that is not the nature of an active roadway that is designed to flex, absorb and transfer the vehicle wheel-load pressures along its length. Sealants applied at the perimeter of the patch and to the over-cuts of conventional pavement saws at the corners, only contribute to waterproof integrity as long as they remain intact and completely fill the kerf or void. Because the vertical joint between the two asphalt layers is inherently weak, it is susceptible to flexing which causes the grouting material to pull away from one side or the other or, in the case of sealants, to be squeezed-out by the action of traffic. This allows ground water to penetrate into the sub-surface where, today, it is acknowledged to be the leading cause of premature pavement failure and potholes.

Even the geometry of conventional repair procedures is suspect. The almost universal requirement that utility cut repairs be rectangular in shape and formed with straight edges running parallel to, or at right angles with the traffic flow, can actually make the situation worse. The rectangular shape causes pressure to concentrate in the corners that causes cracks in the repaired section that permit the infiltration of ground water. A circular keyhole has no corners and, thus, no pressure cracks will develop. The requirement that the lines of the repair be oriented in the direction of the traffic flow, may help to make the repair "look neat", but structurally can lead to differential pressures or wheel loads on either side of the cut that helps to expel the sealant and open the cut. Either way, the preoccupation with rectilinear pavement restoration geometry, mandated in most jurisdictions, may be more of a problem than a solution.

As can be seen in Figure 3, size also matters. The smaller and more precise excavation and permanent repair of a keyhole core requires no subsequent paving or milling and overlay, performs better and is much more aesthetically pleasing than the larger rectangular road cuts

***Figure 3:*** Size matters. (Left) An 18” diameter circular keyhole is less than half the size of a standard 2-foot x 4-foot cut and, because it is circular, has no corners in which to develop pressure cracks. (Center and Right) The large conventional repair of a 2-foot x 2-foot utility cut with a 1-foot cut back all around (making the area to be repaired 4-feet x 4-feet), is much more intrusive that the 18-inch keyhole behind or the series of keyholes on the right.

And T-section cut backs, in which the existing asphalt is cut back from between 12 to 24-inches beyond the original excavation, and the pavement removed prior to the installation of new HMA, in addition to adding significantly to the cost of restoration, are of little help.

Not only is a second cutting required, but what began as a 2-foot by 3-foot opening, with a 2-foot cutback, now becomes a 6-foot by 7-foot opening, that increases the area that must be restored *seven-fold* – from 6 sq. feet to 42 sq. feet. That means that *seven times as much* sound pavement has to be removed and disposed of, and *seven times as much* new HMA must be provided to complete the restoration.

Proponents of the cutback theory argue that the additional cost and effort is justified because it can add structural strength to the repair and provide a better seal against water intrusion. But, while both are admirable objectives, there is no evidence to suggest that either is achieved by the cutback[3].

Structural strength is supposedly gained by some kind of bridging effect. But bridging strength is normally not found in a visco-elastic material like asphalt. Moreover, laboratory research, done on full-size cuts, using servo-hydraulic equipment capable of providing millions of repetitions of heavy wheel loads, found that it was poor soil compaction that was the overwhelming cause of settlement or deflection, and that poor soil compaction was not in any way mitigated by the cutback[4].

As far as moisture penetration is concerned, the cutback is supposed to reduce this by creating a more complex path for the water to follow. But this too seems doubtful, especially from a process that actually increases the potential for infiltration by extending the perimeter of a 2-foot by 3-foot cut, with a 2-foot cutback, from 10 linear feet to 28 linear feet – almost *three times as long*. If one of the problems sought to be overcome by this process is the failure to devise a reliable and long lasting method of sealing the crack between the patch and the remaining pavement, then it is difficult to see how trebling the length of the area of potential failure, can have a salutary effect on the repair.

**Coring and Reinstatement has been Field Proven over 15 years.**

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 50,000 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 minimize traffic disruption; high bond strength to exceed AASHTO standards (safety factor) and create an effective, 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; a wide range of operating temperatures to extend use of the process; and non-hazardous impact on crews and public.

In addition to these prescriptive performance characteristics, according to Golder Associates, 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 regain its design ability to share and transfer the effect of traffic loading from one section to another. This is a “hot-button” issue for those who are responsible for maintaining the road systems.

The Golder Associates study spanned the period 1992 to 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*™*)* that had been specially designed for the process. Golder continued to monitor the effectiveness of the process for a period of 10 years and in April 2003[5] 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.”

***Figure 4:*** 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 gray 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 (center) 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.

The Golder Associates 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.

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[6] that 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 out-performed 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.

In the conventional excavation and repair settlement and deflection had occurred along the wheel path 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 excavation, compared to 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, as compared to the standard cut, and the circular shape eliminated 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 minimize 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.”

**Fast Strength Gain (30 minutes) that supports 50,000 lbs forms basis of Toronto Standard**

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[7]. The comparative testing of three commercially availed 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 50,000 lbs]. Since all three materials ultimately achieve high safety factors against core punch out, it is reasonable to emphasize 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.”

These 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 the promulgation in November 2007 of the TS 4.70: *Construction Specification for Keyhole Excavation and Permanent Reinstatement of Keyhole Cores* [8] that establishes the first comprehensive set of acceptance and performance standards for the keyhole coring and reinstatement process.

The Standard is far-reaching and comprehensive. The maximum diameter of the core is specified to be 460 mm or 18-inches, but, with prior approval of the city, larger cores up to 610 mm 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 required to actually perform the repair work.

***Figure 5:*** Sometimes two cores may be better than one. For example, a locate may be slightly off or a larger opening may be required to make the repair or properly locate and identify the infrastructure. In that case, a second or overlapping core may be cut to expose the infrastructure. When the work has been completed and the excavation backfilled, the two cores can be reinstated as a permanent repair using the same technique as for a single core.

The minimum depth of asphalt or flexible pavements in which the process may be employed is fixed at 100 mm 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 vertical adjustment to ensure that the core is cut in an alignment perpendicular to the horizon.

The Standard establishes minimum performance criteria for the high-strength bonding material 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 70ºF, achieves an equivalent traffic loadable condition that is at least two (2) times greater than the AASHTO H-25 standard or 30,000 lbs.

In the event that the keyhole cut cannot be reinstated within 24 hours, or a temporary covering is required to restore traffic flow, the Standard mandates the use of a 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 traffic conditions.

These road plates, which weigh about 40 lbs and are easily handled by one person, allow the road to be reopened again to traffic while other aspects of the work are being performed. This results in better scheduling of operations and less inconvenience for the public.

For example, as shown in Figure 6, in the City of Toronto, Enbridge Gas Distribution needed to tie in a new 4-inch gas main laid down the west side of a busy arterial street, to services in residences and businesses on the east side, using directional drilling. Before the drill pits were dug through the sidewalk on the west side, a series of five cores were cut in the roadway along the intended drill paths to “pothole” and identify the exact location of potential north-south conflicts that included a 24-inch water main, an 8-inch water main, a 6-inch gas line and two electrical and telephone lines running under the sidewalk on the east side of the street.

In order to make the most efficient use of the drilling crews time, the cores were cut and the conflicts exposed by vacuum excavation in advance of the drill shots and road plates inserted to allow the road to be kept open to traffic. When all of the potholes in two or three blocks had been dug, the directional drill arrived on scene and began its work of safely completing the connection. A core reinstatement crew followed up backfilling and reinstating the cores and the entire project of more than 4.5 miles was completed in this manner. Except for very brief periods of time, at least two lanes of traffic remained open at all times.

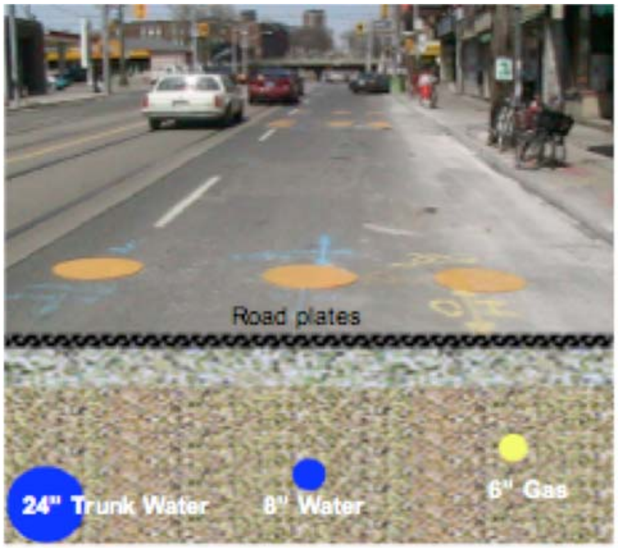

***Figure 6:*** (View: Bathurst Street in Toronto looking north.) Pothole cores are cut to identify potential conflicts during HDD and temporarily capped with a circular road plate that allows traffic to flow uninterrupted on this busy thoroughfare while directional drilling takes place.

## Conclusion

The coring and reinstatement process has been field proven and is currently employed in North America and the United Kingdom by more than 30 leading gas and other utilities and their contractors. It saves both time and money for everyone involved, consumes far less energy and raw materials than conventional repair methods, reduces harmful emissions to the atmosphere, results in shorter and fewer road closings, is more convenient for the traveling public and the neighbors and causes less damage to the road system and the environment than conventional excavation methods.

Rather than jackhammers, pavement breaking devices and backhoes that disrupt or damage the adjacent pavement structures, the excavation is accomplished with the surgical accuracy of a pavement-cutting saw. The circular geometry of the cut itself eliminates the possibility of corner pressure cracks that typically plague conventional rectangular pavement repairs and are the major cause of infiltration of ground water that ultimately results in potholes.

The process utilizes the very same materials used to build the original roadway to permanently restore the utility cut in an environmentally friendly way. No pavement spoil is created, no additional paving material or resources are consumed and no volatile organic compounds or other harmful emissions escape to the atmosphere. Most important is the fact that this is a quick, cost-effective and easy permanent repair that allows the road to be safely reopened to traffic again within just 30 minutes of the completion of the underground work and requires no subsequent road closing to carry out a permanent repair.

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