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A Cost Saving Strategy for Minimizing Pavement Restoration Costs

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ABSTRACT

The cost of installing and maintaining underground utilities continues to increase. Pavement restoration costs can be reduced by as much as 80% by employing new and safer construction techniques such as the keyhole coring and reinstatement process developed and field proven over 20 years in the gas industry.

We all know that trenchless technology has the potential to save millions of dollars when used for gas or water-pipe renewal, but the cost of restoring hundreds of excavations needed to reconnect service laterals robs those trenchless processes of much of their economies. Reconnection of service laterals is the most costly aspect of the job because they are the most numerous. On a typical residential street conventional pavement restoration costs can add $40-50 per foot to the overall cost of the rehabilitation project. That's $250,000 per mile of main. Employing keyhole coring and reinstatement methods to find and reconnect the service lateral avoids most of this restoration cost and the scarring of the streetscape.

Keyhole technology can also be effectively used to locate underground facilities for pre-engineering activities or avoid potential underground conflicts when directional drilling. Other applications include locating and mapping underground infrastructure, deploying internal inspection cameras in buried pipes, installing equipment to evaluate integrity of buried pipelines from the outside using Broadband Electromagnetic (BEM) inspection, and cost effectively removing valves or other obstructions in abandoned gas or water mains to reuse that abandoned infrastructure as a conduit for new fiber-optic cable under congested streets.

Like microsurgery in the medical field, the keyhole technology process enables utility crews to safely and cost-effectively conduct main replacement activities, locate underground infrastructure, and perform repair or maintenance work from the road surface through 18" or 24" diameter 'keyholes' cored through the pavement, thereby avoiding more costly, disruptive and inherently more dangerous excavation methods. The reinstated pavement cores result in a permanent, almost invisible, perfectly matching, waterproof pavement repair that can maintain the performance life of asphalt and concrete pavements and significantly reduce traffic delays and inconvenience to the public.

Keyholes are smaller and less destructive to the pavement. They will not sink, allow infiltration of groundwater, or become future potholes. The reinstated core will support a wheel load of 50,000 lbs in just 30 minutes, as documented in testing performed by the University of Illinois. It is a reliable, field-proven process with more than 20 years of use and over 250,000 successful core reinstatements.

In addition to reducing cost and public inconvenience, keyhole technology is also an environmentally friendly process that eliminates the need for new paving materials and the disposal of old, by reusing the same materials that were originally used to build the roadway to restore it after the excavation. The coring and reinstatement process reduces the carbon footprint of utility cuts and pavement restorations to one-twelfth of that generated by conventional means and avoids the consumption of millions of tons of asphalt paving materials and the disposal of millions of cubic feet of asphalt spoil every year in utility cut repairs.

A Cost Saving Strategy for Minimizing Pavement Restoration Costs

"Infrastructure is the foundation of our society and our economy. The hidden costs of deteriorating, outdated, and under-performing infrastructure—to human welfare, property, and economic activity—are too great to be ignored. Whether acknowledged or not, these costs will continue to grow as infrastructure ages and deteriorates." – [Canadian Infrastructure Report Card in September 2012]

Introduction

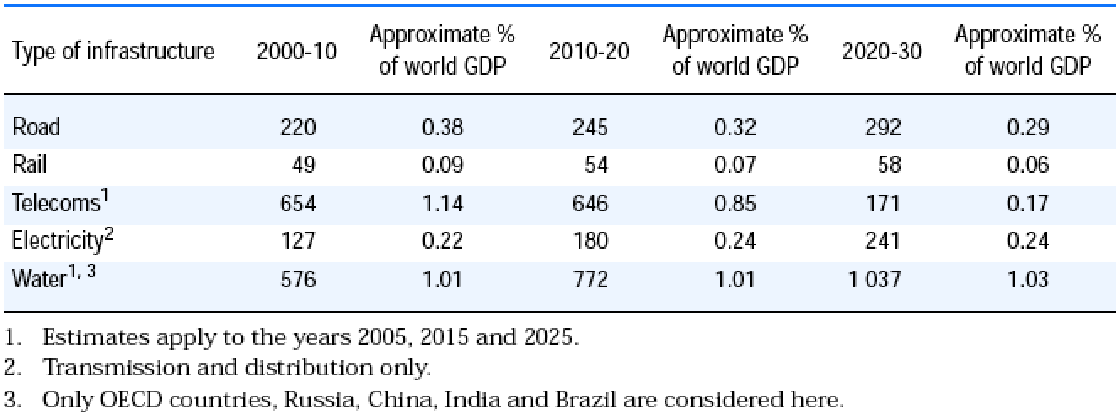
As complex as public infrastructure systems are, they have one common denominator: Over time and with use they will wear out and must be replaced. Many are buried underground and are difficult to access, inspect, and maintain. They are, in effect *"out of site and out of mind"* or invisible. However, the roads and public thoroughfares are not. Their failure is evident to all every day.

This paper identifies a core strategy for addressing the short-term issues of pavement failure related to utility excavations using solutions with long-term benefits. In doing so, it focuses on the need for highway agencies and municipal public work officials to provide and maintain a smooth and safe road surface, while addressing assessment, inspection, and maintenance of utility infrastructures buried under the roads. As time goes on, more of the underground utility infrastructure reaches the end of its useful life, and more utility excavations will be required to maintain and replace this aging infrastructure.

Aging Infrastructure

Much of the world's infrastructure is well past its useful life and needs to be replaced. The Organization for Economic Co-operation and Development (OECD) states in its study entitled *Infrastructure to 2030: Telecom, Land Transport, Water and Electricity (2006)* [ISBN 92-64-02398-4] the annual funding requirements between 2010-20 for OECD countries to maintain, upgrade, and/or replace deteriorating existing road assets over time (*i.e.* net additions and maintenance/replacement) could exceed US$245 billion (See Table 1). [OECD Table 1.1 Page 29], and the conventional sources to support those expenses are lacking.

Table 1. OECD Estimates of Infrastructure Replacement Costs 2000-2030



Type of infrastructure	2000-10	Approximate % of world GDP	2010-20	Approximate % of world GDP	2020-30	Approximate % of world GDP
Road	220	0.38	245	0.32	292	0.29
Rail	49	0.09	54	0.07	58	0.06
Telecoms[1]	654	1.14	646	0.85	171	0.17
Electricity[2]	127	0.22	180	0.24	241	0.24
Water[1, 3]	576	1.01	772	1.01	1 037	1.03

1. Estimates apply to the years 2005, 2015 and 2025.
2. Transmission and distribution only.
3. Only OECD countries, Russia, China, India and Brazil are considered here.

This is a worldwide issue. In the United States, more than 25% of the nation's major urban roadways – highways and major streets and routes for commuters and commerce – are in poor condition. These critical links in the nation's transportation system carry 78% of the approximately 2 trillion miles driven annually in urban America. [P.1 TRIP Bumpy Roads Ahead: America's Roughest Rides and Strategies to make our Roads Smoother October 3, 2013]

According to the American Society of Civil Engineers (ASCE), the United States infrastructure deficit in the roads sector is more than $40 billion a year.

In Canada, more than half (52.6 %) of the roads are in fair to poor or very poor condition. The replacement cost of these assets totals $171.8 billion. [Canadian Infrastructure Report Card (2012)]. Canada's infrastructure gap requires an investment of six to ten times the level of current annual government infrastructure spending. Canada's local governments alone face a $60 billion annual infrastructure deficit–a number growing at a rate of $2 billion a year.

These investment requirements are staggering and beyond the reach of any existing government tax or user fee-based funding program.

However, building new roads is not the answer either. Between 1988 and 2008 the United States built an additional 131,723 miles of roads -- enough new roads to circle the globe more than five times. [Brookings, *"A Bridge to Somewhere: Rethinking American Transportation for the 21st Century," 2008.*] The United States cannot seem to build enough roads to meet the growing transportation demand. Exploring and adopting new pavement excavation and restoration technologies and practices that are better for the roads and help to extend the service life of a road or highway are options that need to be considered.

The Core Strategy

Every day, utility excavations are performed in pavements in order to install, inspect, and repair gas, communications, water, and wastewater infrastructure. They are also used to locate potential conflicts or obstructions when performing horizontal directional drilling or to map existing infrastructure during subsurface utility engineering (SUE). These activities involve cutting a small hole in the pavement through which the underground utility is exposed by vacuum excavation.

Once the inspection, installation, or repair work has been completed, if the excavation is not restored properly, the repaired pavement will settle (see Figure 1) relative to the original pavement or crack and allow groundwater to penetrate into the subgrade. The most common cause of pavement failures, subsidence and potholes is this groundwater.

Figure 1. Traditional utility restoration

Figure 2. Keyhole pavement restoration

Keyhole Technology

Keyhole technology is a process of excavating a small, precisely controlled circular hole in the right-of-way to allow utility technicians to gain access to the buried infrastructure to install or 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 subsurface utility engineering (SUE) in the planning and design stages of highway construction.

Figures 3 and 4. Pavement coring to expose underground utilities

The process employs a truck- or trailer-mounted rotary coring device to core (cut) a small 18-24-inch diameter (450-600mm) hole through the pavement. The pavement core is extracted and set aside to allow vacuum excavation to expose the underground facility (see Figures 3-4). After the underground work has been completed and the hole is 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 (see Figure 5). No pavement spoil is created and no new paving materials are required to repair the road surface. The road can be safely reopened to traffic within 30 minutes of the repair, thus reducing traffic congestion and public inconvenience.

Figure 5. Pavement core being reinstated after the underground work has been completed,

Not only can the road be reopened sooner after the original excavation than with conventional restoration methods, but there is no need to subsequently shut down traffic again for the permanent pavement repairs. This results in a further reduction of road closure time of between two to three hours. In this way keyhole technology for pavement excavation and restoration can reduce the duration of this kind of utility cut repair by an average of three to four hours. If the process was used nationwide for all of the small-hole utility cuts performed in streets every year, it could reduce road closures by 2.8 million hours (See Table 2) and have a major impact on local traffic and the environment.

Table 2. Potential Annual Savings from Keyhole Technology

Activity	**Annual Savings of Keyhole Methods Compared with Conventional Excavation and Restoration Methods**
Reduction in asphalt pavement used[1]:	1.7 million tons -- enough to resurface 1000 lane miles with 3” asphalt paving
Reduction in spoil disposal:	23.5 million cu. ft. -- enough to fill 32,000 dump trucks
Reduction in work zone delay:	2.8 million hours[2] 1.9 million gal fuel[3] $520 million cost[3]
Restoration cost savings to utilities:	$340 to $900 million (estimate)
Reduction in GHG emissions:	320,000 Tons of GHG Emissions This is equal to CO_2 emissions from an Average US Power Plant[4] (2.8 billion tons CO_2 ÷ 8000 power plants)

[1] Assumes: 800,000 small hole 2ft x 4ft excavation of 8in deep composite pavement comprising 3in asphalt over 5in concrete with 1ft cutback on permanent restoration.
[2] Average 3.5 hours shorter road closings x 800,000 excavations
[3] TTI *Urban Mobility Report 2012*
[4] 8000 Power Plants in USA annually generate 2.8 billion tons CO_2 Average: 350,000 tons CO_2.

Geometry of Pavement cuts

Even the geometry of conventional pavement excavations is suspect. The almost universal insistence by municipal authorities that utility excavations and repairs be rectangular in shape and formed with straight edges running parallel or at right angles to the traffic flow actually increases the likelihood of pavement failure. The rectangular shape of the conventional utility cut allows pressure from traffic to concentrate in the corners of the repair, by as much as 4 times as in the rest of the structure. This pressure can cause cracks in the corners of the pavement abutting the repaired section through which groundwater can penetrate into the subsoil leading to premature pavement failure (see Figure 6).

Figure 6. Pressure cracks emanating from the corners of traditional utility cuts

A circular keyhole has no corners in which pressure cracks can develop. Neither are there any sawing over-cuts – which are another access point for ground water -- in the precise circular coring process. However, the greatest barrier to groundwater penetration is the specialized bonding compound used to reinstate the core. Not only does it completely fill the annular space around the core, but when it hydrates it creates a mechanical, waterproof joint between the core and the remaining pavement. This restores the load bearing and transfer capacity of the pavement system to its pre-excavation levels (See Figure 7).

Figure 7. Test cores cut through the kerf on each side of a reinstated core show complete penetration of the bonding compound (thin grey line in the center) through the asphalt and concrete layers of the core. Long term performance via mechanical waterproof joint created by bonding compound.

By eliminating the major sources of ground water penetration and by restoring the pavement to its original load transfer capabilities, keyhole coring and reinstatement can significantly extend the performance and life of the pavement.

Pavement Cut Methods

How pavement cuts are made is also important. Jackhammers and backhoes disturb not only the neighbors as they chop through the pavement, but they also have a damaging effect on the base course, sub grade soils around and below the cut, as well as on the surrounding pavement itself. This affected area is called the ‘zone of influence’ and can extend out three feet beyond the actual cut (see Figures 8 and 9). The residual impact on the soils within this unexcavated zone significantly contributes to the decline in pavement life.

Figures 8 and 9. Damage around the utility cut caused by jackhammers and backhoes

Size of Pavement Cuts

As shown in Figure 10, the size of the pavement cut also matters. Laparoscopic surgeons have known for years that smaller and more precise incisions are better for the patient. The recovery period is shorter, the incision heals faster, leaves a smaller scar and reduces the operation cost.

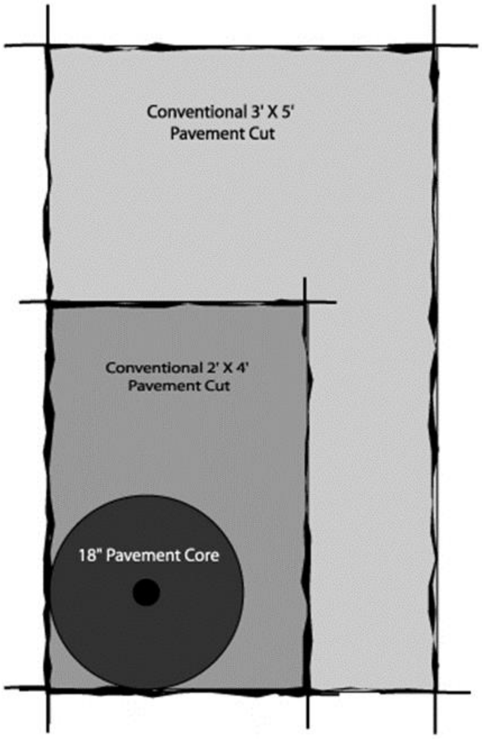


Figure 10. Sizes of utility cuts – 18 inch diameter pavement core, 2 foot x 4 foot and 3 foot x 5 foot traditional utility cuts

The same holds true for keyhole pavement cuts. The smaller and more precise the excavation, the less damage to the road system, which can be repaired quickly resulting in a smaller footprint. Because a reinstated keyhole core is a permanent repair and requires no subsequent paving or overlay, it costs less, performs better, and is much more aesthetically pleasing than conventional rectangular road cuts. Instead of the punishing impact of heavy equipment like backhoes or pavement breakers that can cause collateral damage to the surrounding pavement both at and below the surface, the precise keyhole coring operation has no extended zone of adverse influence. As a result, these smaller more precise circular pavement cuts can also help to extend pavement life.

Other conventional restoration methods like T-section cut-backs do not appear to work well. As practiced in many jurisdictions, a T-section cut-back involves the cutting and removal of the existing layer of asphalt from between 12 and 24-inches (30.5–61cm) beyond the original excavation, prior to the installation of the new asphalt surface. Not only does it cost more and involve a second saw cutting (with its problematic over cuts at the corners), but it increases the size of the excavations and repair. With a two foot (0.6m) cut-back, what began as a two-foot by three-foot (0.6 x 0.9m) opening, now becomes a six-foot by seven-foot (1.83–2.13m) opening. This increases the restored area from 6 square feet (5.6m) to 42 square feet (3.9m^2). This means seven times as much pavement has to be removed and disposed of, and seven times as much new hot mix asphalt needs to be provided to complete the restoration.

Proponents of the T-section cut-back theory argue that the additional cost and effort are justified because it can add to the structural strength of the repair and provide a better seal against water intrusion. However, there is no evidence to suggest either is achieved by the cut-back. [Todres, H.A. (1999), ‘Utility cuts in asphalt pavements: Best engineering practice’, sponsored by the National Research Council Canada and the Canadian Public Works Association.]

The cut-back theory is also supposed to reduce groundwater penetration by creating a more complex path for the water to follow. Yet the cut-back itself actually increases the potential for infiltration by significantly increasing the perimeter of the cut. For example, the perimeter of a two-foot (0.6m) by three-foot (0.9m) excavation, with a two-foot cut-back, grows from 10 linear feet (3m) to 28 linear feet (8.5m) -- almost three times as long -- through which ground water will inevitably pass when the material used to seal the joint is expelled by the action of traffic.

Measuring Social and Other Costs

The actual cost of pavement maintenance and the reduction in the pavement life cycle are important concerns of highway agencies and municipal public works officials. They seek technologies to provide and maintain a smooth and safe road surface for the roads and streets before and after a repair and/or restoration.

Every year local municipalities in the United States issue more than 3.6 million road cut permits. Some of these are for major trenching projects and others are for small holes used for utility repairs and daylighting. They are also used to identify the location of underground infrastructure when directional drilling or in road design and planning efforts. Gas Technology Institute estimates that between 20-25% or about 800,000 of those permits, could be candidates for the keyhole coring and reinstatement process.

In the United States, the Texas Transportation Institute every year prepares and issues the *Urban Mobility Report* that estimates the impact of traffic congestion and its causes, including work zone delay, in terms of wasted time, wasted fuel and the impact on the environment. When grouping the results of their most recent study with the actual on-the-ground savings of keyhole excavation over the conventional alternative, which include an average of saving of 3.5 hours of road closure per keyhole excavation, substantial savings occur. The savings continue to increase as more keyhole projects are undertaken and new keyhole applications are developed.

In Table 2, if the process had been used in 800,000 cases, where it was practical to do so, work-zone congestion could have been reduced nationwide by about 2.8 million hours. By reducing the *Urban Mobility Report* numbers by 90% to account for only work zone delays, and a further 80% to account for only small hole excavations, keyhole excavations would have saved more than 58 million gallons (220 million L) of otherwise wasted fuel and $2.4 billion in cost of wasted time and fuel. Significant savings are also found in 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.

Traffic congestion caused by roadwork carries real costs of its own such as business interruption, environmental pollution, wasteful consumption of scarce resources, and can even increase prices for consumers.. For example, in testimony before Congress, General Mills, one of the world's largest food companies, estimated that for every one mile per hour reduction in average speed of its trucking shipments, below posted limits, annual shipping costs would increase by $2 million. [*U.S. House of Representatives Committee on Transportation and Infrastructure, "A Blueprint for Investment and Reform," June 17, 2009.]*. In similar testimony, United Parcel Service (UPS), calculated that if congestion caused each UPS delivery driver to incur 5 minutes of delay, it would cost the company an additional $100 million in transportation costs annually. [*William Dorey, Granite Construction Co., Testimony before U.S. Senate Committee on Environment and Public Works, Jan. 26, 2011.]*

These social costs of delayed travel time and traffic jams can amount to several times the direct cost of the actual roadwork. They also do not appear to be included in the equation of municipal permitting and regulation that seems predisposed to conventional open cut trenching.

Keyhole in Europe

The move to keyhole coring and restoration technology is not a local or North American phenomenon. In Europe traffic delay and congestion is identified as the major component of the problem, but other costs due to disruption of businesses, damage to pavements, and motor vehicles, as well as an increased number of accidents are also an issue. The annual costs of these problems were estimated to be in excess of €80 billion or about €10 million per hour. [GERG, “Street Works Position Paper in support of Underground Technologies, January 2009] In an already crowded Europe, where traffic demand cannot be met by increasing the amount of road space, they are looking to regulatory systems and newer technology to remedy the situation.

In the United Kingdom, utility street works are disruptive to the economic and social fabric of the country. The indirect costs of such works have been estimated to be of the order of £2 Billion per year. [Brady K.C, Burtwell M. and Thomson J.C. *Mitigating the disruption caused by utility street works*, London, 2001]

The New Roads and Street Works Act 1991 in the United Kingdom introduced a new system of managing utilities’ street works, intended to reduce disruption by seeking a better method of coordination. It led to a number of municipal roadway control measures seeking to achieve a greater balance between the conflicting interests of road users and those undertaking utility street works. Indirectly it has also fostered a renewed interest in trenchless technologies and in keyhole coring and reinstatement technologies as a better and more efficient method of maintenance and repair.

Beginning in 2005 with a decision to import keyhole coring technology and equipment employed by its North American subsidiary, National Grid UK began a pilot project in and around London, to explore the reputed benefits of coring and reinstatement. The successful proof of process resulted in the full-scale implementation of the program in 2007 with the purchase and deployment of several coring units and vacuum excavators. Recently, the program has been expanded by the purchase of an additional six new combined coring and vacuum units.

In 2013 a similar program of coring and reinstatement called *“CorVac”* was implemented in Scotland by Scottish Gas Networks.

In its position paper in support of underground technologies published in 2009 [GERG January 2009], the European Gas Research Group (GERG) determined that a significant investment in innovative technologies was needed to address the growing problems associated with utility street works. Such street works include the disposal of waste materials, disruption, traffic delays, environmental pollution (extra greenhouse gas emissions, noise, etc.) and a reduced quality of life for citizens.

> “It’s clear that what is needed is a significant European investment in innovative technologies to enable utilities and road authorities to identify, locate, inspect, install and renew buried infrastructure with minimum disruption to the street environment. It’s only by minimizing, or even eliminating, the length of time that utilities need to work in the street that we will see reductions in congestion and improvements in traffic flow.
>
> There can be no doubt that this is a European, indeed worldwide, problem with implications for a sustainable environment, energy efficiency in transport, citizens’ health and quality of life and, as such, needs to be addressed in a European Forum.” (Page 2)
>
> “Innovative techniques, such as a circular cut-out in the surface, a technique developed, in particular, by UTILICOR (US) and enabling a cut-out of about 24 inches or 60 cm to be made in the road surface, are a relevant response. The advantage of this technique, apart from an appreciable gain productivity, is the possibility of reusing the piece cut out to reinstate the surface after the backfill stage; this makes the presence of a connection practically invisible at the surface.”
> http://www.gerg.eu/public/uploads/files/publications/position_papers/position_paper_jan09.pdf (Page 17)

Reduced Carbon Footprint

Keyhole coring and reinstatement technology can also have an environmentally positive impact on utility construction and highway maintenance operations. The coring and reinstatement process significantly reduces the carbon footprint of utility cuts and pavement repair. It minimizes the atmospheric emissions of greenhouse gases by simplifying and shortening the maintenance and repair process. This reduces the consumption of millions of tons of asphalt paving materials and the disposal costs of millions of cubic feet of asphalt spoil every year in utility cut repairs.

Keyhole coring and reinstatement, in conjunction with other trenchless technology methods, offer an environmentally sensitive alternative for installing and connecting new gas, water, and telecommunications 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, results in considerably higher greenhouse gas and other emissions into the atmosphere compared with keyhole methods. Keyhole methods have minimal onsite equipment requirements: a coring unit, a vacuum excavator and a hand-held pogo tamper compaction device.

Not only does keyhole coring and reinstatement use fewer pieces of equipment than conventional excavation and restoration, it also reuses the same core of pavement to permanently repair the roadway after the underground work has been performed. There is no spoil to be disposed of and no need for additional paving materials.

In addition, 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. This avoids the emission into the atmosphere of additional volatile organic compounds from newly laid asphalt pavement.

Using a standard carbon calculator, the substantial energy consumption and carbon emissions from the ten or more pieces of construction and transportation equipment involved in the transportation, excavation, and temporary and permanent restoration of a conventional utility cut has been calculated to be 365lbs (165kg) of CO_2. This is compared with 60lbs (27kg) of CO_2 generated by the two pieces of equipment used in the keyhole process.

In addition, both of these procedures use a certain quantity of cement in the restoration process. According to industry metrics, for every pound of cement produced, the equivalent of one pound of CO_2 is released into the atmosphere. A typical 2 ft x 4 ft (0.6m x 1.2m) composite pavement restoration consumes 480 lbs (218kgs) of cement. On the other hand, the volume of cement in the Utilibond core-bonding compound needed to reinstate a comparable keyhole core is only 9lbs (4kgs).

As such, the total CO_2 emissions from every conventional excavation restoration would be 845lbs (383kgs) of carbon equivalents as compared with only 69lbs (31kgs) for the keyhole process. The total Carbon Footprint of a keyhole repair is less than one-twelfth the size of a conventional small hole excavation and repair.

This is a huge environmental benefit. For example, if the keyhole process was used in the 800,000 situations for which it was suited in the United States, there would have been an aggregate reduction or lowering of CO_2 emissions by a total of 310,400 tons per year.

Considering that on average each of the 8,000 power plants in the United States emits about 338,000 tons of CO_2 per year, then the annual reduction in greenhouse gas emissions by employing the keyhole process would be almost equivalent to the closure of one of those power plants.

Conclusions

Because infrastructure (roads and bridges, underground utility piping and cable, and sewers) is at the very heart of economic and social development, society needs to invest large amounts of time and money repairing and rehabilitating existing infrastructure systems in an attempt to put off the more costly renewal of the system identified above by the OECD. At the same time, those responsible for managing this enterprise need to look at new and better ways of maintaining and renewing their infrastructure.

For most transportation authorities and agencies, this change in outlook requires a marked degree of openness and a change in mindset in the way things are done that may not seem apparent today. Typically, maintenance is done quickly and cheaply or, in the case of the restoration of utility cuts, by simply passing on the cost of the pavement restoration to the utility and its ratepayers. A new way recognizes the need to invest more effort initially into a maintenance task by employing and encouraging better techniques in excavation and pavement repairs in order to get a better, long-term performance of the road and its underground infrastructure.

While infrastructure assets generally have long service lives of up to 40 years for urban arterial roads, the decision making process governing their repair and replacement is much shorter. While roads have a long economic lifecycle, they are subject to a 10-year or more capital planning and budgeting cycle. Both those cycles are in dramatic conflict with the 3 to 5 year political cycle and the 2 to 3 year municipal budgetary cycle. As the OECD points out, whenever there is a short-term economic crisis, long-term plans for road construction will be sacrificed for short-term expediency to meet other, more pressing political pressures and policy agenda goals. [OECD p 46].

It is a common goal of asset owners (cities, utilities, and citizens) to efficiently and safely manage and maintain the assets. Keyhole technology can play a small but important role in that process. Keyhole technology also supports reducing greenhouse gas emissions as well as addressing quick access to roadways once a repair is completed.