RePLAY: Green Technology for the Future

Paul Levy, Student of Civil Engineering

2012

RePLAY: Green Technology for the Future

Prepared for

D.C. Lawrence,

Professor of Communication

Prepared by

Paul Levy,

Student of Civil Engineering

April 16, 2012

Summary

The most common road surface in use today is asphalt pavement. While a durable and versatile construction material, it is susceptible to oxidation from the sun and exposure to air. Oxidation leads to the pavement becoming brittle, and cracks will form. If the cracks go untreated, they will widen and eventually potholes will develop. As the pavement deteriorates, maintenance and repair measures are necessary to maintain the surface, primarily in the form of sealants, and filling of cracks and potholes. As the roadway nears the end of its service life, maintenance measures are no longer sufficient to preserve the integrity of the surface, and the road must be resurfaced.

RePLAY Agricultural Oil Seal & Preservation Agent is an asphalt sealant which is 88% biobased, 40% of which is sourced from soybean oil. It penetrates deep into the surface of the pavement, adding lost oils to the asphalt, filling cracks, and reducing the oxidation process, thus adding years to the service life of the roadway. Making use of agricultural and recycled materials, it is a non-toxic, environmentally friendly alternative to petroleum-based sealing agents. In addition to it not having a negative effect on the environment, the process of growing the crops needed to manufacture the product remove harmful carbon dioxide from the air, making at not only have no carbon footprint, but be overall carbon negative. RePLAY is widely accepted in the United States, and is quickly gaining positive attention in Canada, being tested in several cities. RePLAY's ability to add up to five years of service life to a roadway after its first application, and to preserve a road surface with subsequent applications, has the potential to save municipalities a great deal of money in reduced maintenance and road reconstruction costs. This product has the potential to double the service life of a roadway, if applied shortly after installation and re-applied in five-year intervals. The immense cost savings and environmental benefits make RePLAY a product worth investigating.

Table of Contents

Introduction

There is a great need today to make efficient use of our resources. Roadways comprise a large portion of any municipality's financial responsibilities, with larger cities having roadway assets valued in billions of dollars. The maintenance and reconstruction of these roadways is a serious concern, and often prioritization of maintenance and eventual resurfacing leads to roadways waiting until they are at the absolute end of their service life before they are resurfaced. Conventional sealing methods can be a vital part of the maintenance process, but eventually the road surface will fail.

Sheldon Chesky, founder and CEO of BioSpan Technologies in Ballwin, Missouri, had a vision of a product which would leverage biotechnology to extend the lifespan of a roadway, while not having negative effects on the environment. In the late 1990s, he formulated RePLAY, a roadway sealant which is 88% bio-based, and commenced testing. In 2003, the product became available on the open market, and is now widely used in the United States, and is quickly gaining attention in Canada, as well as globally.

The basic function of RePLAY is that it reverses the harmful effects of oxidation of a road's surface. It helps seal cracks, fill voids, and repel water. Most importantly, a single application of RePLAY can extend the service life of a pavement surface by up to five years. Successive applications five years apart can continue to renew the surface, potentially doubling the service life at a fraction of the cost of resurfacing. This significant savings is what is gaining the attention of municipalities, particularly since the product is also eco-friendly.

In a time when global warming and other environmental concerns are at an all-time high, it is important for municipalities to be seen as proactive in pursuing environmental issues, and making use of green technologies. RePLAY is not only non-toxic, the process of growing the agricultural materials

needed to make it actually consumes carbon dioxide in the atmosphere, making it one of the few carbon-negative products on the market today that are used in the construction and maintenance of roads.

RePLAY represents the first in a long line of biobased products that are being developed by BioSpan technologies, partially funded by the United Soybean Board in the United States. As demand grows in Canada, there is an eventual plan to build a RePLAY manufacturing plant in Ontario, leveraging Canadian soybeans to maintain Canadian roads. As we move forward, green technologies such as these will be key in maintaining our way and quality of life for future generations.

Asphalt

Basic Structure

Asphalt pavement is the most common form of road surfacing used today. Simply stated, asphalt pavement is made up of bituminous materials (or bitumens), aggregate and air voids. "Bituminous materials are hydrocarbons that are soluble in carbon bisulphate. They are usually fairly hard at normal temperatures. When heated they soften and flow. When mixed with aggregates in their fluid state and allowed to cool, they solidify and bid the aggregates together, forming a pavement surface." (Atkins, 2003) An important aspect of the strength of asphalt pavement is the density of the pavement, specifically the air voids in the mix. The air voids allow ductility of the pavement, allowing it to flex under heavy loads, and prevent the asphalt cement from bleeding to the surface of the pavement. If the percentage of air voids is too high, the pavement is permeable, and allows water and air to enter the pavement, leading to the acceleration of oxidization and damage during freeze-thaw cycles. If the percentage of air voids is too low, movement of the pavement as it deflects squeezes asphalt cement to the surface, reducing skid resistance. A combination of mix design and proper construction techniques are utilized, and together achieve the target density for the finished pavement surface.

Common Failures

Over time, asphalt pavement will deteriorate. Recurring loading caused by vehicle traffic causes compaction of the pavement over time, reducing the overall air voids, and eventually causes fatigue resulting from repeated deflections of the pavement surface. Fatigue will result in cracking and rutting of the pavement surface. As water gathers in the ruts and infiltrates the cracks, freeze-thaw cycles will result in the cracks expanding. As these cracks expand, more water is allowed into the structure of the pavement, eventually leading to damage beneath the travelled surface of the pavement, those layers

which provide the strength to the overall structure. Deterioration of the sub-base and finally the gravel base beneath the pavement will lead to the ultimate failure of the pavement surface in the form of large cracks, potholes, and edge raveling as the pavement breaks off at the edges. Proper mix design and construction will forestall the onset of these modes of failure, but the pavement will eventually fail regardless unless proper maintenance procedures are carried out. Unfortunately, workmanship is another telling factor in road construction, and errors in the asphalt cement mix, improper handling techniques, improper installation techniques, and soil conditions that are different than the designs anticipated all play factors in the pavement suffering premature failure. Oxidation of the asphalt cement occurs over time as a result of exposure of the pavement to sunlight and oxygen, and results in the oils in the asphalt cement becoming thicker resins, and those resins in turn becoming hard, brittle asphaltenes. Oxidation also leads to hairline cracking of the pavement surface as the pavement loses the ductility it needs to recover from deflection under load. These cracks permit both water, which leads to acceleration of cracking as described above, but also add additional avenues for oxygen to penetrate the asphalt, further accelerating the oxidation process. Another result of oxidation is the aggregate at the surface of the pavement will break free from the pavement, resulting in reduced skid resistance as there is less contact with the tires of vehicles, and thus less friction.

Maintenance

When the pavement surface shows signs of deterioration, preventative maintenance and repairs can be carried out, to extend the service life of the roadway. A seal coating can be applied, which helps the asphalt to retain its oils and aggregate and will serve to seal small cracks at the surface. Sealants are typically petroleum-based, and while assisting with the retention of oils and the prevention of oxidation, will not add strength to the surface or stop cracks that have already progressed beyond hairline cracking. Cracks, where they appear, can be repaired by the injection of an adhesive sealant into the

crack, which will arrest further lengthening and widening of the crack. These sealants rarely penetrate the full depth of the crack, however, and once they start to weaken, the crack will expand at an accelerated rate. Potholes and edge rutting can be repaired by patching, replacing the missing pavement with new asphalt cement and hand compacting, allowing traffic to fully compact the replacement material. The appearance of potholes and edge raveling are generally signs of more significant problems in the pavement's base layers, and thus patching is only a temporary solution at best. As the pavement ages, these problems become more prevalent as the asphalt cement loses its ability to bind the aggregate together. Ultimately, the cost of spot repairs such as these become prohibitive, and the decision is made to resurface the roadway (Asphalt Pavement Distress Summary, 2009).

RePLAY

Overview

RePLAY Agricultural Oil Seal and Preservation Agent is an asphalt sealant that is made from 88% bio-based material, 40% of which is derived from soybean oil (Kindler, 2009). The remainder is primarily recycled materials, particularly polystyrene, which is used to impart polymers to the asphalt. It was first developed and tested in 1996 by Sheldon Chesky, CEO of BioSpan Technologies as a green alternative to petroleum-based topical sealants, and was introduced to the open market in the United States in 2003. RePLAY seals the surface of the pavement filling air voids and hairline cracks, preventing water infiltration, and reversing the effects of oxidation by replacing oils to the asphalt cement as well as adding polymers to strengthen it. The overall effect of RePLAY is to add to the usable service life of the pavement, up to five years with a single application. RePLAY is applied to the road surface using a sprayer containing the product loaded into the back of a pickup or flatbed truck, as shown in Figure 1,

below. A GPS system is used, to ensure that the application of the spray is precise, and that the spray will be even. Only two workers are needed to apply the spray, one driver and another to monitor the spraying equipment on the back of the truck. A kilometre of road takes approximate one and a half hours to apply, and the road can be opened to traffic 15-30 minutes after application. The product will not harm lines on the road, or painted traffic symbols on the road's surface. RePLAY has been in wide use in the United States since 2003 and in Canada since 2009. RePLAY is now used in 19 States in the United States, three provinces in Canada, and six countries worldwide. Preliminary Canadian testing has been performed in Vancouver, Edmonton, Calgary, Regina, and in 2010 the first tests in Ontario were carried out in Bruce County, near Owen Sound. It is the hope of Bob Jamieson, owner of Surface Green Solutions, Ontario retailer of RePLAY, to generate sufficient demand for the product in Ontario to justify a Canadian production plant in Ontario, thus leveraging local resources for the product. (Ontario Good Roads Association, 2011)

Figure 1: RePLAY being applied to a road surface

Sustainable Practices

In an effort to maintain sustainability in today's road surfacing practices, it has become necessary to review the methods and materials used in both the construction and maintenance of our roadways. Advances in construction methods, such as increased use of recycled asphalt pavement and warm mix technology, have decreased the impact paving has on the environment. The developer of RePLAY aims to take the process a step further, utilizing the rejuvenating aspects of the product to extend the lifespan of the pavement, potentially even doubling it. By extending the pavement's service life, a great deal of money will be saved due to the reduction of labour and materials used to maintain and repair the pavement surface. Since RePLAY is 88% biobased, and also utilizes recycled materials, it is comprised almost entirely of renewable resources. Most similar products are derived from petroleum, a resource which, due to ever-increasing demand and dwindling reserves, is possibly one of the least sustainable materials used today. By making use of renewable, agriculture-based materials, RePLAY not only reduces the need to use petroleum-based products in pavement maintenance, but also reduces the need to use bitumen in the manufacture of new asphalt by allowing the road surface to last longer.

One of the most prominent initiatives in the use of sustainable practices today is the drive to make greater use of soy-based products. In the United States, one half of one percent of the net market price of soybeans is assessed, usually when the farmer sells his product to the grain elevator. Half of these funds are invested by a state soybean board, and the other half is forwarded to the national body, the United Soybean Board (USB). These boards, both at the state and national levels, invest the collected funds to promote soybean marketing, production technology, and to fund the development for new uses for soybeans (Kenneth Payne, 2011). The USB provided funding to BioSpan Technologies for the development of RePLAY. In Canada, there is a similar initiative called Soy 20/20. "The Soy 20/20 Project brings government, academic and industry partners together to stimulate and seize new global

bioscience opportunities for Canadian soybeans. The Project assists researchers, industry, producers and policy makers in focussing on key opportunities and working together to achieve them" (Soy 20/20, 2011).

The aim to promote RePLAY in Canada in general, and Ontario in specific, is under the purview of Soy 20/20. As mentioned earlier, it is the hope that sufficient demand for RePLAY will be generated to construct a processing plant in Ontario to produce RePLAY. Canada is the seventh largest producer of soybeans in the world, and the majority of those soybeans are grown in Southern Ontario. It requires slightly more than 36 bushels of soybeans, what might be produced by one acre of crop, to produce enough soybean oil to manufacture a kilometre's application of RePLAY. There is no concern that utilizing soybeans in this way would reduce the amount of soybeans available as food. There is currently a substantial oversupply of soybeans on the Canadian market, and RePLAY only makes use of the soybean's oil. Soybean oil makes up approximately nineteen percent of the bean, and the remainder can be used in high-protein animal feed, thus significantly reducing waste. This would represent a lucrative new market opportunity for Ontario farmers (Ontario Good Roads Association, 2011).

Carbon Footprint

Another crucial element in today's environmental concerns is the addition of carbon, generally in the form of carbon dioxide, into our atmosphere. The amount of carbon contributed to the environment by a particular activity or entity is referred to as its carbon footprint. During the early stages of Earth's formation, the atmosphere contained a significant amount of carbon dioxide, more than would allow most forms of animal life to survive today. Plant life, which absorbs carbon dioxide from the air, retains the carbon as a nutrient, and releases the oxygen back into the atmosphere as a by-product, allowed sufficient oxygen levels to develop in the atmosphere over the course of several million years to allow the survival of larger animal life on the surface of the planet. This plant life, as it

died, was eventually buried, became fossilized, and formed the fossil fuels we use today, such as oil and coal, in the form of hydrocarbons. As these fossil fuels are burned, they release the carbon they had had absorbed back into the atmosphere. In essence, we are releasing several millions of year's worth of absorbed carbon into the atmosphere in a relatively short span of several decades. Unless action is taken to drastically reduce the amount of carbon being released into our atmosphere, we will make the air we breathe toxic once again.

In the spring of 2009, a Life Cycle Assessment BEES analysis (Building for Environmental and Economic Sustainability) was carried out for RePLAY, in order to determine its environmental impact, from its manufacture through to its eventual breakdown into the environment. BEES is a software package developed by the National Institute for Standards and Technology in the United States in order to determine the environmental impact of building materials. "BEES measures the environmental performance of building products by using the life-cycle assessment approach specified in the ISO 14040 series of standards. All stages in the life of a product are analyzed: raw material acquisition, manufacture, transportation, installation, use, and recycling and waste management. Economic performance is measured using the ASTM standard life-cycle cost method, which covers the costs of initial investment, replacement, operation, maintenance and repair, and disposal" (Lippiatt, 2011). The BEES analysis was carried out, comparing RePLAY to a petroleum-based asphalt treatment called Reclamite.

The assessment determined that Reclamite increased the amount of carbon dioxide in the environment, thus increasing the potential of global warming, and when compared to RePLAY required a greater amount of fuel energy of the course of its life cycle. RePLAY was demonstrated to in fact reduce the amount of carbon dioxide in the atmosphere, since no carbon dioxide is produced in its manufacture, and the process of growing the agricultural materials used to make the product consumes

carbon dioxide. Overall, it was determined that the Reclamite contributed over 1200kg of carbon dioxide to the environment in its life cycle, where RePLAY in fact removed nearly 400kg, the small amounts of carbon dioxide added during manufacture, transportation and application being completely offset by the amount consumed during the production of the source materials (BioSpan Technologies, Inc., 2009). Figure 2, below, shows the results of the assessment.

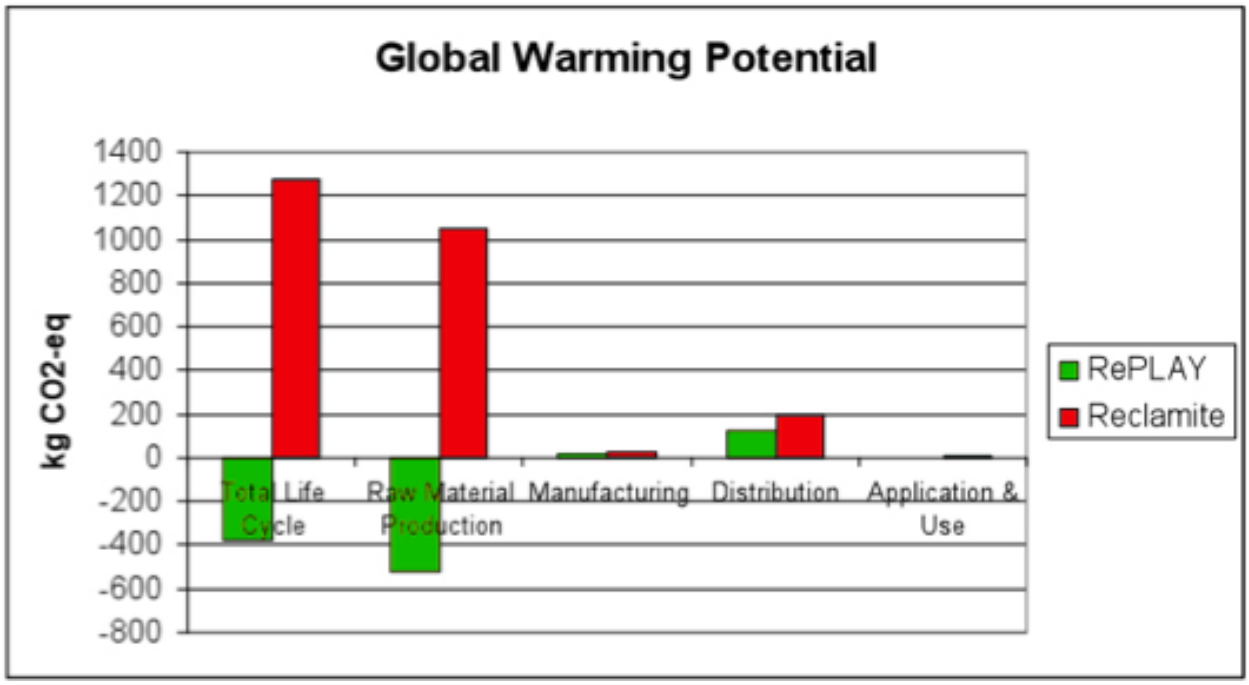

Figure 2: Life Cycle Assessment of RePLAY vs Reclamite

Adaptation in the United States

RePLAY has been received well in the United States. Thus far, 19 states have applied RePLAY since it was introduced to the open market in 2003, with a total use of over 100000 multi-lane miles (BioSpan Technologies, Inc., 2010). RePLAY has had a particularly warm reception in the state of Ohio, with at least one municipality the Village of Spencerville, adopting the standard practice of applying RePLAY to all of its newly paved streets since first using the product in 2005. "'With the rising costs of paving, I feel

this is an effective means of extending the life of our streets; ultimately resulting in a tremendous cost savings for the Village's budget,' said Spencerville Village Administrator Sean Chapman. He pointed to a specific street on which they applied RePLAY for $1,300, instead of spending approximately $17,000 to repave the street. 'We see this product as a way to extend the life of our streets at a fraction of the cost of traditional paving or sealing,' Chapman added" (United Soybean Council, 2009). The United States Air Force has also taken an interest in the product, approving a test application of the product on the runways at Tyndall Air Force Base in Florida in May of 2009. The cost of applying RePLAY, and extending the life of the runway's surface, would be far less than the cost of installing a new pavement surface (Biobased Today, 2010).

Introduction to Canadian Market

RePLAY is exclusively distributed in Canada by Bio Protection Solutions, located in Kelowna, British Columbia. The City of Edmonton, Alberta in 2008 applied RePLAY to two roads as a trial. The roads were exhibiting hairline cracking a few months after application, an indicator of either an asphalt mix of insufficient strength, or improper rolling techniques. Three weeks following the trial application, cores were taken and revealed that the cracks had been sealed to their full depth (Donovan, 2008). A trial application of RePLAY in Canada was applied on two recently resurfaced streets in the City of Vancouver in April of 2010. John Marino, Superintendent of Streets Operations Branch for the City of Vancouver, indicated that the City was primarily interested in using RePLAY for two aspects: the green aspect that it was a bio-based product without the negative environmental impacts of petroleum-based products, and the long-term savings potential of making a road last longer (Marino, 2010). In June of 2010, two streets were treated in the City of Regina, Saskatchewan with RePLAY to address the pavement surface being overly porous. The cores taken after testing indicated that the pores had been filled, and sand patch tests demonstrated diminished texture depth, an indicator of improved skid resistance (Massier, 2010).

In September of 2010, a kilometre-long stretch of County Road 3 near Own Sound, Ontario had an application of RePLAY, a 4-year old roadway beginning to demonstrate hairline cracking. Core samples taken in November of 2010 indicated a penetration depth of 5cm, and the cracks were filled (Ontario Good Roads Association, 2011).

Results/Benefits

Resistance to Deterioration

The primary benefit of RePLAY is that it extends the life of the pavement surface; generally 5 additional years of service life can be gained from a single application. It accomplishes this by penetrating 20-50cm deep into the pavement, filling air voids and cracks, replacing oils in the asphalt lost due to oxidation, and adding polymers to the asphalt cement. By restoring these oils, the harmful effects of oxidation due to sunlight and exposure to oxygen can be arrested, and reversed. The treatment should ideally be applied within two weeks of repaving, but before three years. Within the first three years of installation, the asphalt cement loses approximately 50% of its oils and polymers, thus making it a good candidate for rejuvenation. As with any preventative maintenance, earliest applications are best. By re-applying every three to five years, the normal deterioration of the road surface can be prevented, allowing a road surface to last significantly longer than an untreated surface (BioSpan Technologies, Inc., 2010). RePLAY contains SBS (styrene-butadiene-styrene) and SBBS (styrene-butadiene-butadiene-styrene) polymers, common admixtures in asphalt to assist in pavement flexibility in colder conditions such as those commonly experienced here in Ontario, and are typically used in Superpave applications.

Improvements to Surface

In addition to the retardation of further surface deterioration, and the reversal of oxidation effects, RePLAY can also improve the surface it has been applied to. A common problem with roll-on petroleum-based sealants is that they decrease skid resistance. This decrease in skid resistance is generally considered to be ameliorated by the improvement to the road surface. A common test of a road surface's skid resistance is a sand patch test. A pre-determined small measure of Ottawa River Sand (a variety of sand used in materials testing due to its uniform grain size) is placed on the road surface, and then spread using a hard rubber spreading tool into a circular patch, with the surface depressions filled to the level of the peaks in the pavement. Measurements of the diameter of the resulting circle are taken, and then can be used to calculate the average depth of the sand based on the volume spread. As skid resistance is influenced by the amount of surface contact a tire has with the pavement, a reduction in the texture depth will result in an increase in skid resistance. Sand patch tests performed before and after applications of RePLAY have demonstrated no increase in texture depth, and most frequently show a reduction in texture depth (Massier, 2010).

In addition to skid resistance, the application of RePLAY creates a barrier to water on the surface of the pavement, preventing infiltration into pores, voids, and cracks. In our northern climate, freeze-thaw cycles result in the expansion of water that was trapped in these cracks and voids, leading to a cyclical behaviour of the crack widening and more water being able to penetrate the surface of the pavement. As the water further penetrates the surface, the lower layers of pavement, and ultimately the granular base of the roadway will be affected. Damage to the structure underlying the pavement will lead to larger cracks appearing elsewhere in the pavement, potholes, ravelling of the edges of the roadway, and upheaval or settlement of the pavement, creating a bumpy surface (Asphalt Pavement Distress Summary, 2009). All of these conditions can be prevented using RePLAY, preventing the process from occurring before it starts. It is worth noting that if the roadway is already displaying symptoms of structural failure, such as raveling of the edges, potholes, or alligator cracking (interconnected crack

patterns that resemble a reptile skin's scaled texture), the road should instead be re-paved. While RePLAY can serve to stabilize the surface, it cannot stop exiting problems beneath the surface which will eventually lead to the roadway returning to its original gravel state (BioSpan Technologies, Inc., 2010).

Financial Considerations

While improvements to the surface and increased longevity of the service life of a roadway are desirable, ultimately it is the financial cost of any particular application which will be a key metric in determining where municipal and provincial dollars are spent. One of the largest assets that any municipality owns is its road network, with large cities having inventories that value in the billions. The maintenance of these roadways, and their eventual resurfacing or reconstruction, comprises a large portion of any municipal budget. As the cost of oil increases, so does the cost of using bitumen as asphalt cement; the cost of a barrel of oil has doubled within the past decade, and shows no sign of slowing. As the cost of pavement continues to rise, municipalities have been forced to re-evaluate how they will pay to maintain their roadways into the future. Paving a roadway is an expensive process, with a cost in the tens of thousands of dollars. Given an average width of seven metres for two lanes, a kilometer of road could cost $175000. A road surface tends to remain in serviceable condition for 15-17 years, after which point it begins to deteriorate rapidly, and the cost of frequently repairing the cracks and potholes that form cause resurfacing to be a more economical option. After 20 years, the service life will be complete, and resurfacing is required for the road to remain usable. Over the course of 40 years, the cost of paving, maintaining and resurfacing a roadway with an area of 10000 square metres would cost approximately $500000.

When a newly paved road has RePLAY applied, its maximum usable life immediately increases by five years to 25 years. If for the following fifteen years RePLAY was re-applied every five years, the same road would have an overall cost of just $108000. As mentioned earlier, the best practice for

preventative maintenance is to apply it early. RePLAY costs two to three dollars per square metre to apply, and is usable while the roadway is in good condition. As it begins to degrade and form significant cracks and potholes, repair and patching measures can cost between ten and twenty dollars a square metre. Once a roadway deteriorates to the point that reconstruction is the only option, the cost escalates to between 30 and 50 dollars per square metre (Oliver, 2010).

Conclusion

At this time, the most efficient means of surfacing our roadways is to use asphalt-based pavements. These pavements are, however, susceptible to environmental factors accelerating their breakdown. The most prominent of these factors are oxidation, caused by sunlight and oxygen, and cracking, which is accelerated once begun by the infiltration of water and subsequent freeze-thaw cycles. These factors lead to the asphalt cracking, potholes forming, the edges of the road ravelling, and ultimately the failure of the entire road surface. These issues can be repaired by sealing the cracks and filling potholes and ravelled edges, but as time goes on the road will eventually return to its gravel state at the end of its service life, at which point there is no recourse but to resurface the roadway.

There is a variety of asphalt sealants on the market, all targeted at prolonging the service life of roadways. As the cost of oil continues to rise, the associated cost of paving our roads rises with it. At the same time, Federal and Provincial funding for road construction and maintenance diminishes, and thus there is ample encouragement on the part of municipalities to attempt to make the most from their paving dollar. In the past decade, pavement restoration and preservation has become an industry unto itself as municipalities seek ways of easing the financial burden of road maintenance. The majority of these products are petroleum-based, and thus are also affected by the increasing price in oil.

Another critical issue to consider is the need for sustainable, green technologies. The use of fossil fuels such as oil has an environmental burden in the form of their carbon footprint: the volume of carbon dioxide contributed to the air both by the combustion and processing of oil. Additionally, the world's oil reserves are finite, and we are swiftly reaching the point when the peak oil production will be past; that point when all of the easily accessible oil has been exploited, and only those reserves which require a greater effort to extract, such as the oil sands in Alberta, will be left. When this occurs, the price of oil will increase at an even greater rate, as the cost of extraction is passed on to the consumer.

All of these factors point to the need to reduce the cost of our roadways in such a way that we can use sustainable practices that do not harm the environment. RePLAY is an example of just such a product. Its ability to rejuvenate a pavement surface, reversing the effects of oxidation, as well as protect it from further damage, thus extending the service life of the road, will lead to immense savings on the part of municipalities. The deep penetration achieved by RePLAY outstrips the performance of conventional sealants, which while concealing signs of deterioration and filling surface cracks, fail to repair damage below the surface, allowing the process to begin once the sealant itself deteriorates. RePLAY's ability to seal cracks and voids deep beneath the surface sets it apart from other products. The ability to add five years to the service life of a road with each application, provided the roadways are treated every five years, could potentially create a perpetual surface: one that would not require costly resurfacing or maintenance.

In addition to the monetary gains to be had by making use of RePLAY, it has the additional advantage of not having a negative impact on the environment. RePLAY is non-toxic, meaning that if it is used in an agricultural area, it poses no threat to crops. In fact, the only potential hazard to plant life is over-spraying, which will cause the tops of the affected plants to die back, but they will immediately begin to grow again. In addition to this, while petroleum-based products contribute carbon dioxide to

the environment in the process of collecting and refining the raw materials needed, the plants that are grown to produce the agricultural oils which make up 88% of RePLAY consume carbon dioxide while they are growing, in effect reducing the overall amount of carbon dioxide in the atmosphere, thus making RePLAY carbon negative overall. RePLAY also makes use of recycled polystyrene to supply the styrene-butadiene-styrene and SBBS styrene-butadiene-butadiene-styrene polymers it adds to asphalt to strengthen it, thus also making use of post-consumer waste.

Overall, making use of RePLAY makes good sense, both from a financial standpoint, and an environmental one. As we move forward, we need to be constantly looking for ways to ensure that future generations can enjoy the quality of life that we have, both the benefits of civilization, such as roadways, and the ability to enjoy the air we breathe. Products such as RePLAY, and innovators in the world of biotechnology such as Sheldon Chesky, will be instrumental in ensuring that our future will be a bright one.

Works Cited

Asphalt Pavement Distress Summary. (2009). Retrieved from Asphalt Institute: http://www.asphaltinstitute.org/public/engineering/maintenance_rehab/distress_summary.asp

Atkins, H. N. (2003). *Highway Materials, Soils, and Concretes, Fourth Edition.* Upper Saddle River, NJ: Pearson Education, Inc.

Biobased Today. (2010, July 22). Air Force Tests Soy-Based Asphalt Sealer on Runways. *Biobased Today*.

BioSpan Technologies, Inc. (2009, August 13). *Life Cycle Assessment*. Retrieved from BioSpan Technologies, Inc.: http://biospantech.com/life-cycle-assessment

BioSpan Technologies, Inc. (2010, May 24). *RePLAY Frequently Asked Questions.* Retrieved from BioSpan Technologies, Inc.: http://replay.biospantech.com/wp-content/uploads/2010/04/RePLAY_FAQ.pdf

Donovan, H. B. (2008, October 16). Construction Services Engineer, City of Edmonton. *Letter to Blue Steel Chemicals*. Edmonton, Alberta, Canada.

Kenneth Payne. (2011). *The National Soybean Checkoff and the Soybean Promotion, Reasearch & Consumer Informnation Act and Order*. Retrieved from http://www.soybeancheckoff.com/index.htm

Kindler, J. (2009, Spring). Soybeans Are Extending the Life of Ohio Roadways. *Ohio Soybean Review*, p. 21.

Lippiatt, B. (2011, April 18). *Software BEES*. Retrieved from National Instituite for Standards and Technology: http://www.nist.gov/el/economics/BEESSoftware.cfm

Marino, J. (2010, April 23). Superintendent, Streets Operations Branch of City of Vancouver. (C. News, Interviewer)

Massier, D. (2010, July 5). RePlay Agricultural Oil Seal and Preservation Agent. Regina, Sakatchewan, Canada.

Oliver, G. (2010, January 8). *Bio Protection Solutions Presentation.* Retrieved from Bio Protection Solutions: http://bioprotectionsolutions.com/assets/files/biospanproductPresentation(1).pdf

Ontario Good Roads Association. (2011, February). Sealing The Deal With Soybeans. *OGRA's Milestones*, pp. 35, 37.

Soy 20/20. (2011). *Soy 20/20 About US*. Retrieved from Soy 20/20: http://soy2020.ca/about.php#soy2020

United Soybean Council. (2009, Spring). Soy-Based Products 'Road Ready'. *Biobased Solutions For Government*.