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INCORPORATING INFRARED HEATING TECHNOLOGY IN CRACK REPAIR OPERATIONS FOR AIRPORT RUNWAYS AND TAXIWAYS

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Abstract: As demand for travel by aircraft steadily increases, airports are becoming busier than ever. Airfield pavement loads are therefore increasing in turn by both weight and frequency. As climate change causes more extreme and hazardous weather conditions, the environmental loading on runways and taxiways also becomes more severe. Regular maintenance and repair operations are necessary to maintain an adequate level of service for these airfield pavement surfaces. Increased cost, frequency and time restrictions for these pavement repairs are a result of this growing demand for air travel. One of the most common pavement deficiencies in runways and taxiways is cracking. Most cracking when first established is only a minor deficiency, but when left to propagate can result in major pavement damage and premature pavement replacement. Cracking can also cause small chunks of pavement to separate from the pavement surface, creating debris on the airfield. This kind of debris is referred as foreign object damage (FOD) risk for the aircraft. The increased demand on airfield pavements creates more opportunity for cracking to propagate. New methods for repairing the cracked areas must be considered in order to keep up with airport's increasing pavement repair requirements. Infrared heating is a relatively new crack repair process which uses infrared light to evenly heat the pavement surface. This process heats up the in-place pavement until it is malleable enough to rework, adds rejuvenators to restore some of the pavement's innate properties, then compacts the affected area to repair cracks and other deficiencies. Using the pavement's in place material, or recycled asphalt pavement (RAP) for this repair method has been a cause of concern for airport agencies considering the extremely high performance standards airport runways have for their asphalt materials. Previous studies have shown, however, that reclaimed asphalt material can perform similarly, or even better than 100% virgin materials. The objective of this paper is to analyze the use of infrared heating technology for crack repairs on airfield pavements and compare it to the current crack repair processes used. The benefits and drawbacks of all repair methods will be compared based on performance factors, cost, and repair time. Based on the performance characteristics the repaired pavement achieves utilizing each crack repair method, an ideal pavement repair method will be determined for different locations and crack types on the airfield. The findings of this paper can be used to optimize crack repair practices for runways and taxiways.

1 INTRODUCTION

Runways and taxiways, unlike airport's apron areas, are designed to withstand short term loading by aircrafts taking off, landing, and taxiing. The most common asphalt pavement distress types for airport runways and taxiways are longitudinal cracking, transverse cracking, weathering, block cracking, rutting, ravelling, jet blast and oil spillage (Hajek, J., Hall, J.W., Hein 2011). Routine maintenance is essential in order to stop these distresses form occurring and propagating, causing unsafe conditions for airplanes to operate on. Current pavement repair methods used on these pavement surfaces include crack sealing, patching, and mill and replace.

Infrared heating technology is a relatively new pavement repair technology used most commonly to repair longitudinal cracking, transverse cracking, and small pothole affected or block cracked areas. This is a fast-track repair method which aims to utilize in place and recycled asphalt pavement (RAP) materials to create a repair which will last longer than traditional repair methods.

The objective of this paper is to present the benefits and drawbacks of current airfield flexible pavement repair methods in comparison to those of infrared heating pavement repair technology which would be used to assess and select an ideal repair method for any airfield repair project.

1.1 Background

The invention of the airplane in 1903 sparked the world's desire for rapid travel by air (Anderson Jr. 2003). After World War II aviation technology was advanced enough to begin the age of commercial air travel. Demand for this new mode of transportation has increased rapidly since. Figure 1 below displays the increase in passenger and freight tonne kilometers traveled from 1944 until 2016.

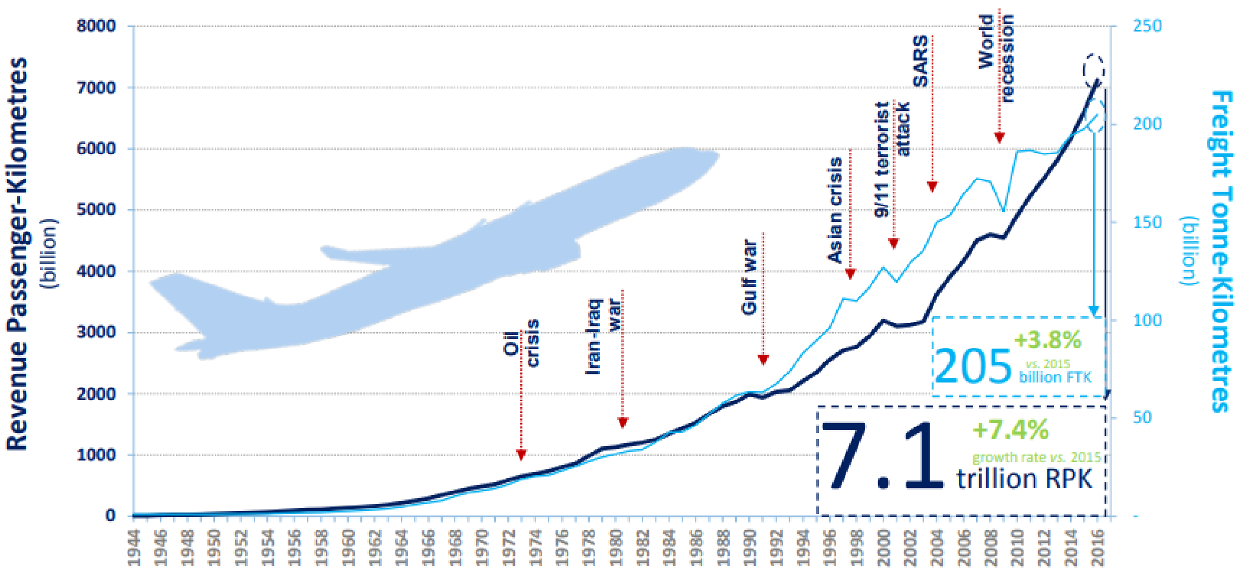

Figure 1: Growth of Air Transport through Scheduled Commercial Traffic (Economic Development Air Transport Bureau 2016)

In 2016, 3.8 billion passengers travelled commercially by air, 53 million tonnes of freight were transported, and 35 million commercial flights were completed (Economic Development Air Transport Bureau 2016). Airlines are accommodating this steady increase in demand by scheduling more flights and purchasing larger planes to carry more passengers and cargo. This in turn puts more stress on existing airport infrastructure. As of 2015, 17,678 commercial airports exist in the world, that number increasing to 41,778 when accounting for private and military airports and aerodromes (Airports Council International 2015). The majority of these airports and aerodromes have unpaved runways and taxiways, but approximately 14,000 airports worldwide have paved asphalt or concrete runways currently in use (indexmundi 2018). The increased weight and frequency of loading on these airfield pavement surfaces causes deterioration of the pavement structure to occur sooner.

This rapidly increasing demand for air travel is not the only problem facing airport infrastructure. Climate change continues to cause more adverse weather conditions worldwide including increased temperature extremes, precipitation, solar radiation, and extreme weather events (Y. Qiao, A. Dawson, T. Parry 2016).

These environmental changes severely affect the performance of pavement structures, reducing service lives significantly. One study completed in 2007 estimated a 30% increase in rehabilitation costs for flexible pavement structures due to the adverse effects of climate change (Cechet 2007).

These changes in stimuli airfield pavement surfaces are experiencing need to be serviced accordingly. It cannot be expected of older maintenance methods to last as long under increased stress. Routine pavement maintenance is required in order for runways and taxiways to run safely and efficiently, but frequent disruptions in airport service result in increased labour and user costs. An optimal pavement repair method should be identified which effectively addresses the pavement deficiencies runways and taxiways are affected by while also accommodating the frequency and time constraints present in today's busy airports.

1.2 Scope

This paper will focus on the performance of some of the more widespread pavement repair methods, in comparison to the use of infrared heating technology on the deficiencies most common to asphalt pavement runways and taxiways. A specific focus will be brought to the performance of these maintenance strategies on longitudinal and transverse surface cracking, as these are typically the first and most common pavement deficiency to occur and propagate on runways and taxiways.

2 CURRENT AIRFIELD REPAIR PRACTICES

2.1 Airfield Maintenance Evaluation Process

Airfield runways and taxiways are required to provide a safe travelling surface for all types of aircraft. When operating larger aircraft, pilots can't properly see the pavement surface around the wheels of their aircraft, so it is vital there are no major pavement distresses to cause damage to the aircraft or veer them off course. When travelling at high speeds during takeoff and landing, running into any sort of debris could severely damage the aircraft. Common airfield pavement distresses including cracking and potholes can loosen small chunks of pavement, increasing foreign object damage (FOD) risk for aircraft. Runways and taxiways must therefore be consistently evaluated to ensure the required performance standards are met. The three main types of airfield pavement evaluation are structural, surface, and friction. Structural evaluation is measured by the pavement classification number (PCN), which is a five part code indicating the bearing strength, pavement type, pavement strength, and maximum allowable tire pressure of the surface. The PCN can be compared to an airplane's aircraft classification number (ACN), which expresses the relative structural loading effect of different pavement types on a specific aircraft. To determine if an aircraft can safely utilize a specific airfield pavement surface, its ACN value is compared the pavement's PCN value. If the aircrafts ACN value is equal or less then the pavement's PCN value, then the pavement surface is structurally able support the aircraft (Transport Canada 2016). When evaluating the surface condition of a runway or taxiway, the pavement condition index (PCI) is used. This process catalogues the type, extent, and severity of all pavement distresses and combined this information to give the pavement section an overall rating out of 100 (Karim, Fareed M.A., Rubasi, Khaled Abdul Haleem, Saleh 2016). Runways in particular require adequate friction in order to safely operate. The friction of airfield pavement surfaces is evaluated through a roughness survey which determines the pavement's surface friction coefficient, macrotexture depth, and skid resistance (Louis Berger Group Inc. 2012).

2.2 Common Repair Methods

According to a study completed by the Airport Cooperative Research Program (ACRP), the most commonly used runway and taxiway repair methods for asphalt concrete pavement structures are crack sealing with hot-poured sealant, small area (pothole) patching with hot and cold asphalt mixtures, and milling and machine patching with asphalt concrete (Hajek, J., Hall, J.W., Hein 2011).

2.2.1 Crack Sealing

Crack sealing maintenance is performed first by cleaning the crack using compressed air, then filling it with a rubberized high modulus crack filling material. This method is generally used on small, lower severity cracks. Benefits for selecting this maintenance method include very low cost and short repair times. The crack sealing repair method is so common that all contractors and workers are familiar with the proper repair process and have all the skills, tools and machinery to complete it efficiently. Crack sealing is considered a short-term or preventative repair method. It is useful to prevent cracking from propagating if the crack is not active, that is the crack does not actively change sizes throughout the seasons, but does not eliminate the deficiency ((Uzarowski, L., Henderson, V., Henderson, M., Kiesswetter 2011).

2.2.2 Small Area Patching/Filling

Areas with more significant cracks or potholes will often be treated with small area patching. This technique is completed by cleaning the affected area, then filling it with virgin materials in the form of a hot or cold asphalt mix. This method is also extremely common and simple to perform, with short repair times and low cost. Hot mix asphalt generally performs much better then cold mix asphalt applications when applied to small area patching. Cold mix asphalt has higher void content then hot mix asphalt, making the patched area more permeable and therefore much more susceptible to damage (Munyagi 2006). Cold mix asphalt will most commonly be used during the winter months when hot mix asphalt cannot be kept sufficiently heated during its cooling process, significantly reducing its structural integrity. Although cold mix asphalt generally has a lower service life then a hot mix patching mixture, it is commonly used on airport runways and taxiways as a temporary patch in winter where a defect is a safety concern. Other benefits of choosing cold mix asphalt over hot mix include lower cost, less construction time, and environmental benefits from huge reduction of energy use between the two mixtures (Munyagi 2006).

2.2.3 Milling and Replacing

When cracks and potholes are more severe, the affected area of asphalt needs to be renewed. The most common method used to achieve this is milling and paving. A milling machine is used to remove the affected asphalt from the pavement surface, and an asphalt paver follows to repave the area with virgin hot mix asphalt. This method is significantly more expensive than the other commonly used repair methods, but is a long-term solution providing the affected area with a brand new surface course instead filling and patching continuously propagating defects (Uzarowski, L., Henderson, V., Henderson, M., Kiesswetter 2011). Longitudinal cracking is often repaired using a smaller milling machine then filled and compacted by workers to reduce maintenance costs.

3 INFRARED HEATING REPAIRS

3.1 What is Infrared Heating?

Infrared heating is a form of asphalt pavement repair which utilizes infrared radiation to evenly heat the affected pavement surface to a specified depth. Infrared heating machinery has been used in pavement repairs for nearly 30 years, but has only recently gained notoriety in the field (Kieswetter 2013).

Infrared light is not visible to the naked eye because it consists of much longer wavelengths then all visible light. When objects are exposed to infrared radiation they absorb these rays in the form of heat (Ray-Tech Infrared Corp., 2017). To produce infrared radiation, propane is fed through a device which mixes the correct ratio of air to propane into a heater plenum which creates ignition. Ignition occurs within a ceramic cloth which heats up to temperatures ranging from 800 to 1000 degrees Celsius (Kieswetter, 2013). This hot surface of the ceramic cloth is lowered close to the pavement surface so the infrared radiation impinges the asphalt. Figure 2 below displays an infrared heating machine with a close up on the heated ceramic cloth.

Figure 2: Left: Infrared Heating Machine in Use; Right: Bottom of Machine in Use (Kieswetter, 2013)

3.2 Repair Processes

3.2.1 Surface Cracking and Pothole Repairs

When repairing a section of pavement using infrared heating technology, the following process is recommended: First off, the affected area is heated using the infrared heating machinery to approximately 350ºC, making sure the pavement is evenly heated past the depth of the cracked areas. Workers then rake the now malleable asphalt to remove damages and add virgin asphalt, or a RAP mixture to bring the area back up to grade if necessary (mostly during pothole repairs). During this stage, a product called a rejuvenator is added to the heated area in order for the affected pavement to regain some of its innate properties. When asphalt pavement ages it loses these chemicals over time and become more stiff, hard, and prone to cracking; adding the rejuvenators when the pavement is soft makes the pavement more flexible. Finally, the area is compacted, making sure a strong thermal bond is created between the pavement surrounding the affected area and the rejuvenated asphalt (Parker 2007). Sections of pavement repaired using this method often last longer than conventional repair methods before further deteriorating because of this thermal bond. This thermal bond is created because both the repaired area and the pavement surrounding that area are heated when the joint between them is compacted. Compared to the cold joint created when using the more conventional repair methods, the thermal bond will not allow any water or debris into the joint (Ray-Tech Infrared Corp. 2017). Figure 3 below displays the general repair process when using infrared heating machinery.

Figure 3: 1) Infrared Heating 2) Scarifying 3) Rejuvenators Added 4) Compaction (Kieswetter, 2013)

3.2.2 Longitudinal Joint Construction and Repairs

Most infrared heating machinery is able to heat asphalt to any temperature desired with reliable accuracy (Huang et al. 2010). Another common use for this machinery is heating up a longitudinal joint during construction to ensure a thermal bond with the asphalt alongside. When constructing a longitudinal joint one would ideally pave the entire width of runway/taxiway at once, or have pavers pave in echelon so the longitudinal joint has a thermal bond connecting it. This is not always possible or cost effective. When pavements are constructed without a thermal bond connecting the longitudinal joints, premature cracking at the joint is bound to occur. With infrared heating used to heat up this cold joint, the pavement life increases accordingly (N.A. 2010).

An infrared heating machine crafted in Kitchener, Ontario has been designed specifically for longitudinal joint construction and longitudinal crack repairs. This infrared heating “train” is 48 feet long and is made of infrared heating mechanisms linked together from end to end. This chain of infrared heating devices can be towed by a bobcat or any other small construction vehicle. During maintenance repair of longitudinal cracking, this machine can be continuously towed along the affected area at a rate of 5 feet/minute (Heat Design Equipment Inc., 2017). By the time the affected pavement has been heated by the entire length of the train, it is at the correct temperature to be scarified, reworked, rejuvenated and compacted by the maintenance workers. Figure 4 below displays this machine in use

Figure 4: Infrared Heating Train (Heat Design Equipment Inc., 2017)

When asphalt is heated without using infrared heating machinery, a conventional flame is most often used. Using a flame to heat asphalt tends to overheat the top layer of asphalt, burning and damaging the asphalt material. Burnt asphalt will not perform well because most of the innate oils will have burned off and the aggregates will be weakened. In place materials heated by a conventional flame burner are not usually heated enough near the bottom of the desired heated section before burning of the top layer occurs. These under heated materials fail to become sufficiently malleable and do not mix properly with added rejuvenators, or create a sufficient thermal bond with connecting asphalt sections (Ding, Huang, and Shu 2016). In comparison, infrared heating is much more reliable to evenly heat the pavement layer to the specified depth with a much lower risk of burning the materials.

3.3 Infrared Heating Projects

An example of a Canadian airport choosing infrared heating technology for a pavement repair project can be found in Kuujjuaq Airport, in northern Quebec. A large transverse crack in the middle of the runway was causing continual problems for aircraft taking off and landing. The crack had sealant applied in it many times but the repairs were not lasting long. Before infrared heating was applied, the remaining previously applied crack sealing has to be removed from the crack. Figure 5 below show the crack in question before and during the infrared repair process.

Figure 5: Kuujjuaq Airport. Left: Crack Before Repairs; Right: Crack During Infrared Heating Repairs (Kieswetter 2013)

Other runway/taxiway repair projects which have utilized infrared heating as their maintenance method include Jean Lesage International Airport in Quebec City used infrared heating while resurfacing a runway, Fort Drum Air Base in New York utilized infrared heating for longitudinal joint construction, and Vancouver International Airport recently used infrared heating for some patch repairs (Kieswetter 2013).

4 COMPARING REPAIR METHODS

When airport management has to determine a method of repair to use on an affected area, several core factors influence these decisions the most. In order to be able to complete all necessary repairs and manage the budget for future maintenance and rehabilitation operations, the cost of repair must be taken into account. Out of all the repair options considered, Crack sealing is by far the cheapest repair option, costing about $8 per linear metre (David Jeong et al. 2015). Costs for crack and pothole filling vary based on type of asphalt used and amount of materials required. Pricing for standard mill and fill crack repairs run in the range of $10-$15 per linear metre. Infrared heating repairs for cracking cost approximately $10-$12 per linear metre (Uzarowski, L., Henderson, V., Henderson, M., Kiesswetter 2011). When completing a repair job using infrared heating, all of the in-place materials are used and recycled so the only material costs are rejuvenator costs. In comparison, when using the mill and resurfacing method, the asphalt layer is replaced with virgin materials. Therefore, when the size of the repair job increases, the relative price of using infrared heating compared to mill and resurface decreases.

The more expensive repair options such as infrared heating and mill and replace are also more effective. The cheaper repair options have to be completed more frequently in order to obtain the same level of service. Airport infrastructure management agencies should complete comprehensive life cycle cost analysis to determine which combination of maintenance/rehabilitation options create the most effective and inexpensive system for each individual airport. Every airport has different environmental and pavement loading conditions which cause varying performance of each maintenance procedure. New methods should be continuously experimented with to make sure airfield pavement structure is performing at the best in can be. For busy airports with tight flight schedules, long maintenance procedures are even more costly due to the high value of time associated with the use of these runways and taxiways.

Another factor when deciding what kind of repair method to choose for a specific project is the availability of that repair method. Commonly used crack repair methods are readily available in all regions of the world, while new methods like infrared heating are not. When a method is not readily available, the machinery would have to be transported a longer distance to the construction site, dramatically increasing the cost of that option.

Table 1 below compares these key decision factors that an airport would consider when choosing an asphalt pavement repair method between crack sealing, crack filling, asphalt milling and replacement, and infrared heating.

Table 1: Comparison of treatment alternatives for crack repair on asphalt pavements

Criteria	Crack Sealing	Crack Filling	Asphalt Milling and Replacement	Infrared Heating
Typical Crack/pothole Size to Repair	Very small	Small	Large	Small-Large
Repair Time	Very low	Very low	Higher	Low
Availability	High	High	High	Low
Initial Cost	Lowest	Lower	Moderate	Moderate
Maintenance & Rehabilitation Frequency	High	High	Low	Expected to be Lower

With the information summarized on Table 1 above, the most appropriate maintenance method for a runway or taxiway repair project can be selected. For small repair projects, one might stick to crack sealing or filling due to their low cost and high accessibility, however, for pavement sections causing continual problems infrared heating repairs should be considered because it provides a longer term solution with minimal repair times. For larger pavement deficiencies where asphalt milling and replacement is required due to poor materials, infrared heating equipment should still be considered as part of the repair process to provide a hot joint between the existing and patched pavement areas.

5 CONCLUSIONS

Airport pavement surfaces require constant evaluation and maintenance in order to operate safely and efficiently. The steady increase of demand for air travel simultaneously reduces the time available and increases the need for maintenance and rehabilitation to occur.

Three of the most common repair treatments used on asphalt pavement airport runways and taxiways (Crack sealing, crack filling, asphalt milling and replacement) were evaluated and compared to the relatively new repair strategy of infrared heating. Some of the key benefits of using infrared heating for crack and pothole repairs include a short repair time, long term repair solution, and the use of RAP materials leading to material cost reduction and environmental benefits. The major drawback of this maintenance option being the fact that as a relatively new technology, the equipment and expertise required to properly execute this repair strategy are not available widespread. This can lead to increased project costs from the extra transportation of workers and machinery.

All airports are unique to their specific maintenance and rehabilitation requirements, and the selection of an optimal treatment strategy should be evaluated on a project-by-project basis. New repair methods need to be tested and implemented in order to improve the overall quality of runway and taxiway infrastructure, and keep up with the increasing demands being placed on airports today.

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