2013 WJTA-IMCA Conference and Expo
September 9-11, 2013 • Houston, Texas

Paper

UHP/LV WATERJET – SURFACE RE-TEXTURIZING FOR BITUMEN FLUSHING / BLEEDING

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ABSTRACT

This paper is designed to provide participants with a rapid understanding of Ultra High Pressure / Low Volume (UHP/LV) water-jet and its applications, including the key benefits and what this means for the future US roading market and broader industry requirement. Interesting facets of the technology are that it uses around 90% less water and produces significantly less mass at point of impact than common alternatives. The effect is a water milling action (versus water stream erosion) that produces high precision cutting capabilities with only minimal residual surface damage, including the ability to treat even very hot bitumen. Low water volume also means much lower back-thrust reaction, so pumps and equipment can have smaller footprints, use less energy and be more portable. The session also examines research and findings from a New Zealand government-backed project to develop a highly automated re-texturizing solution, using UHP/LV technology, to address the large and growing problem of flushing (or bleeding) in chip-seal based bitumen surfaces. The solution is turn-key in approach and has been purpose designed to match the preventative maintenance band of the FWHA / US Pavement Preservation initiative. The paper will conclude with the introduction of a new economic model for DoT's and contractors, made possible by the benefits that UHP/LV technology can uniquely offer.

1.0 INTRODUCTION

This document, and the associated conference presentation, focuses on Aquamax Devco's current research/commercialisation project, identified as Mobile Pavement Preservation Vehicle (MPPV), which encompasses a spectrum of mechanical and electronic developments that support the prime initiative of utilising UHP and UHP/LV water jet systems, to address pavement surface issues for primarily (but not restricted to) treating bitumen (oil) based pavements such as chip seal and asphalt.

In essence, this is a dedicated truck concept that has on-board water jet application, product recovery and treatment systems, and a high level of process automation, including smart data capture via electronics, that is capable of treating a myriad of surface types (multi-purpose).

In 2010, with New Zealand Government backing and co-funding, our vehicle concept research and development programme had progressed to the point that a representative of the USA National Centre for Pavement Preservation (*Associate Director, Steve Varnedoe*) travelled to New Zealand to review and report on our efforts, and to consult on the viability of commercialising the system as a whole, or aspects of the 'breakthrough' technologies, relative to current civil practices and requirements within the USA, of which there were many.

Since 2010, our New Zealand-based program has been progressively reviewed and supported by the USA civil engineering fraternity, primarily through emerging pavement programs, but expanding to include requests for a broader approach such as bridges, pipes and structures.

The USA National Centre for Pavement Preservation (NCPP - 2003) is a quasi-government entity, affiliated with the Michigan State University (MSU) and is primarily focused on fostering new systems and protocols for the extension of pavement and bridge 'operational and life capability', encompassing existing and future structures/utilities.

The historical practices for pavement/bridge maintenance (life extension) are not sufficient to meet the current and future USA federal requirements for state funding, and the perceived notion of 'build/rebuild' is no longer financially acceptable. Therefore, there is an urgent need to realign thinking and processes to accommodate the burgeoning problem of the declining USA civil utilities assets' performance integrity and values.

Pavement surface condition also contributes significantly to vehicle performance safety. Thus when reviewed over a broad spectrum of accident related incidents, from minor through to fatal events, pavement condition can be (and is) argued as a proportional factor in both causing, or contributing to, the severity of many incidents. The cost of vehicle accidents to the nation is prohibitive; therefore new processes are being called for to address this issue by making it more

affordable to maintain a consistently higher (than current) level of pavement surface standard for peak friction performance capacity.

Because of lower build costs relative to other pavement systems (e.g. Asphalt, Concrete), the USA is progressing towards introducing ‘chip seal’ pavement (already well-established in Texas, North Carolina & Virginia) as an economic imperative.

Conversely, chip seal pavement has been common practice in countries such as Australia, New Zealand and South Africa for many years, but pavement life extension practices/developments have been minimal. Therefore, two underlying failure modes have been largely tolerated (raveling and flushing), which are then treated when a worst case scenario dictates the application of an overlay or ‘patch’ repair.

Our work, through the application of UHP and UHP/LV systems, is designed as a foil to these two failure modes, and due to the product [bitumen] being oil based, it is seen as environmentally correct to treat (but not replace) when maintaining a performance specification such as safety friction requirements.

The USA pavement fraternity has expressed a need to have a more scientific and controlled maintenance capability with their commitment to chip seal pavement. Therefore our research, which carries some ‘world first’ processes, will be developed and commercialised in the USA and is fundamentally based around water jet systems.

By placing an emphasis on developing/providing electronic data capture (output /input), we have set in motion a unique generational program that can grow with the overall machinery development with a focus on electronically:

1. Controlling the vehicle’s surface treatment decisions
2. Identifying and logging vehicle location
3. Data stream/location as to pavement condition - by percentage
4. Area treated
5. Cost analysis

Although not directly linked to the water jet technology, these electronic attributes are seen as ultimately changing the surface treatment requirement from a ‘reactive’ to a ‘proactive’ program in the eyes of the civil engineers, from which they can then utilise this collected data for budget and preemptive programming.

In this instance, we have focused on emerging environmental concerns. Thus by replacing the process of major water use with a strong element of water velocity and less water to carry out this treatment procedure, we then relegate water use and subsequent water purifying treatment (for re-use) to a lower rate than envisaged, with the current low pressure/high volume pump systems.

We have not invented water jetting improvements, although Aquamax Devco carries 17 years of knowledge and application in the field. Instead, the focus is on the described value added systems and automation that we specialise in, inclusive of the USA pavement fraternity engagement, and how (and why) this all fits around the prime energy delivery of UHP and UHP/LV pumps.

Aquamax Devco's objectives are to introduce and fully integrate both UHP and UHP/LV systems into the USA civil engineering [future] pavement maintenance market, through the medium of value added automation, recovery and environmental systems.

2.0 WHAT IS UHP/LV?

UHP/LV systems are relatively new on the commercial scene with regards to surface preparation, rather than cutting, and since 1995 Aquamax Devco have been involved with equipment sourced from Flow International, Washington State, USA.

In the early days of this technology, the equipment was somewhat prone to failure. Replacement components were expensive and short lived. Many mechanical re-developments were undertaken by Aquamax Devco, and often worked in conjunction with Flow International's engineers, to resolve the operational issues the equipment was facing.

Low Volume is the key difference from all other UHP systems. With operational pressures of 40,000 PSI (2800 bar) and water volumes as low as 4 ½ litres per minute, the nozzle transition at this pressure converts to a velocity of approximately Mach2 (1500 mph at sea level). UHP/LV is all about minimizing the water volume mass and maximizing the energy as velocity.

3.0 KEY BENEFITS OF UHP/LV

'Low mass' versus 'High mass' is the key difference with UHP/LV. There is a 'productive time factor' versus an 'effective application result' when considering what water volumes to choose for what application. An example of this is the consideration of a ship's hull. It is appreciated that a higher water volume would be desirable, however a soft stone heritage building would not

respond well to a highly erosion-based [large] volume of water flow, especially at a high velocity (Mach number).

The obvious explanation for this is that if a sub-surface (base surface) has an underlying hard nature such as steel, then High Mass/High Velocity works well. Conversely, a soft/yielding base such as beneath a pavement surface where the pavement requires top coat treatment/removal, requires a quick diffusion of energy (mass) so as not to compromise (erode) the under-base structural integrity. Therefore, in this instance, Low Volume – High Velocity water achieves a controlled and desired result.

The method for UHP application, with regards to surface preparation, is by means of a rotating head that houses multiple small orifices (between 5-10+ thousands of an inch) and in the case of UHP/LV, this works predominantly as an ever sharp milling cutter and, due to the Low Water Mass, requires to work the project/job from the top down, therefore having control over the depth of the treatment.

Small equipment means ‘portable’ and ‘compact’ with low back thrust when in operation. These attributes lend themselves effectively to automation, controlled detritus recovery, recycling and data logging/collecting, which describes the roading project that Aquamax Devco is prototyping and trialing.

Furthermore, it stands to reason that through UHP/LV there is the capacity to control immediate waste generation, which is becoming increasingly important when confronted by ever demanding environmental issues and requirements relative to waste management.

4.0 PLATFORM TECHNOLOGY

UHP/LV can be used for a myriad of applications which, in their own right, can be very effective answers to problems associated with their industries.

Currently, examples of existing client and application in New Zealand are geothermal turbines, small ship structures, very tall buildings (both internal and external), and aircraft surface preparation. There are further applications, and as Aquamax Devco discovers more about UHP/LV and its capabilities, the more the applications list grows.

Aquamax Devco’s pavement/roading programme is to automate pavement treatment processes and effect recovery and recycling systems based around its core technology of UHP/LV.

5.0 WHAT IS FLUSHING

Flushing (or bleeding) is where excess bitumen, primarily due to environment and traffic densities, rises to the top of a pavement surface, blanketing the aggregate/stone chip that is critical to the friction value for that pavement. Flushing is primarily a safety hazard relative to the loss of tire friction.

Flushing is an issue that will manifest in the worst possible positions of a pavement, such as (but not limited to) corners (both fast and slow), stop signs/traffic lights, pedestrian crossings, straight road areas (especially dangerous on high speed sections) and very wet/damp areas. The problem is double-edged in that friction dynamics change dramatically between dry and wet, as on one hand (dry), you can have large area tire contact, however on the other hand, when wet, pooling can occur (not all flushing is raised) and therefore an aquaplane situation becomes prevalent. Also, pooling water can contain fuel and oil contaminants that only contribute to the hazard potential.

To treat the problem of flushing, the excess product requires removal and from a Pavement Preservation perspective, the applied removal treatment process must not be detrimental to the integrity of the pavement by removing too much of the pavement binder (bitumen), or penetrating past the binder into the compacted base. A sensible approach, therefore, is to utilise a UHP/LV 'top down' water milling approach.

6.0 GROWING PROBLEM IN THE US?

In 2010, Aquamax Devco commissioned Steve Varnedoe, who at that time represented the USA based National Centre for Pavement Preservation (NCPP) as Associate Director. Steve was commissioned to travel to New Zealand and conduct, through a series of trials, a review of the working Aquamax Devco MPPV pavement preservation vehicle and its potential value to roading relative to the current and future requirements for roading practice and standards. Steve Varnedoe stated that "there is a growing recognition that chip seals are among the most cost-effective preservation treatments for extending the life of all flexible pavement types. Chip seals, however, are susceptible to two modes of failure; ravelling and bleeding."

Ravelling aggregate (chip) will occur when the binder volume has been compromised, such as with aggressive flushing removal or the binder being under applied, such as when laying new or overlay pavement. Ravelling will also occur if a section of pavement is subjected to unreasonable stress, such as high loading or excess temperature, relative to the chosen bitumen composition/grade. Another factor is a natural and time related deterioration of the binder after many years of service due to oxidation and water.

Flushing (bleeding) can occur from a collection of issues such as:

- Too much Bitumen when laying new pavement – *this can be a contractor applying too much binder to guarantee that raveling will not occur over their guarantee period*
- Incorrect 'product hardness' choice (bitumen grade) relative to pavement loadings or temperature
- Temperature/environment
- Overlay applications – *always adding more bitumen to original road structure (saturation potential)*
- General Stress – *not just excessive, but also continuous*
- Underground disturbance or failure points (water, crevices etc.)
- Road re-alignments - adding higher traffic flows or cornering and braking stresses (e.g. installing a round-about)

All in all, there are a myriad of reasons/causes for flushing (bleeding) or raveling to occur, which is why the MPPV vehicle prototype system is being developed as a fast reaction/response machine so that emerging issues can be dealt with prior to becoming a wide spread and expansive problem.

7.0 MPPV PROTOTYPE – LAB ON WHEELS

The Aquamax Devco MPPV vehicle is referred to as our 'lab on wheels'. It represents a collection of systems and technology that have been designed, developed and tested in a laboratory environment, until proven. These systems were then further designed/scaled and fabricated for integration into the MPPV vehicle, to produce for us our mobile testing lab to facilitate field evaluation and implementation of the current and future design integrations.

The list below represents the original goals for the MR1 programme, to which most have been fulfilled to date:

- To specifically address flushing in chip seal-based bitumen aggregates primarily
- To have multi-purpose capability with a small physical and environmental footprint, with an ideal use in compact urban areas
- To have a high degree of automation including intelligent sensors and data capture
- To be able to treat even very hot bitumen (fluid state) without surface damage
- To have an on-board recovery & waste recycling/removal system
- To attract New Zealand Government funding and backing

This is a dedicated plan to develop 'specific' preservation equipment based around maintaining primarily chip seal roads, but also other pavement surfaces. The MPPV design is about 'mobility', 'function', and 'multi-purpose', with the general thrust being that small and compact equipment has a major role to play and requires a different *economic model* of understanding if comparisons are attempted against a 'Big Unit - Large Area Treatment' model. Due to the emerging environmental economics and rising raw material costs, there requires to be a broader understanding/development of what a cost saving model actually might become if there was a more comprehensive and capable system[s] of treatment available, such as an MPPV technology. Some of the MPPV dynamic points of reference are as follows:

- No greater than 4.5 litres of water use, per minute
- Small recovery shroud system (wide area coverage due to cross-linear travel)
- Head movement PLC controlled
- Recovery shroud has no contact to the pavement surface – *no issues of adhesion or blockage*
- Material recovery is by induced 'airflow'
- First stage separation is recovery of air from water/bitumen mix (interceptor)
- Vehicle is controlled hydraulically for programmed forward movement, so no driver is required other than for steering when necessary
- Development of an 'on-board' waste water treatment and recycling system is well advanced – *a process made possible due to very low water usage*

We recognised too that the future is also about captured electronic data for asset management. This would shift the pavement engineer/equipment from the re-active to a pro-active approach, through the accrued data stream that flows as the equipment is in operation mode. This approach can be developed more comprehensively as the MR1 project develops its commercial capabilities – i.e:

- Pavement chip depth percentage
- Pavement surface profile (depressions, raised areas) etc.
- Product amount removed
- Areas that require refill binder (a reversal of removal)
- Industry standard profile of rehabilitation result – plus print out
- Global positioning to identify area treated
- Selectively able to process problem areas by not using a set width approach, thus inhibiting the problem of collateral damage

All in all, bitumen is a very difficult substance to process (i.e. selectively remove, transfer and separate etc.), however the MPPV does this. Aquamax Devco's goal has been that this machine is a purpose-developed intervention process, which is able to treat emerging pavement deterioration issues economically with the capability to capture its processing data.

8.0 TRIAL RESULTS

During the Steve Varnedoe review, tests were carried out on site at the time of each trial, to establish before and after results for the 'effectiveness' of the UHP/LV treatment process on the pavement surface with regards to restoring a high level, quality friction value back into the pavement surface.

The following chart shows the skid test results for the most severe location treated during the trials. The tests were carried out using the British Pendulum Number (BPN) method with the results being highly acceptable, with the pavement returning an excellent reading differential.

Table 3. Wise Street, Skid Resistance

Test Location	Position	BPN Before	BPN After
1	Outer wheel path	54	85
2	Between	84	84
3	Inner wheel path	49	86
4	Outer wheel path	54	81
5	Between	72	86
6	Inner wheel path	49	80

Figure 1. BPN Results for most severe location during Steve Varnedoe trials, Wellington, New Zealand

9.0 PAVEMENT PRESERVATION

Pavement Preservation has been defined by David R. Geiger, Director of Asset Management for US Dot/FHA, as being preventative maintenance that is a planned strategy of cost effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration and maintains or improves the roadways functional condition.

Pavement Preservation Guidelines

	Type of Activity	Increase Capacity	Increase Strength	Reduce Aging	Restore Serviceability
Pavement Preservation	New Construction	X	X	X	X
	Reconstruction	X	X	X	X
	Major (Heavy) Rehabilitation		X	X	X
	Structural Overlay		X	X	X
	Minor (Light) Rehabilitation			X	X
	Preventive Maintenance			X	X
	Routine Maintenance				X
	Corrective (Reactive) Maintenance				X
	Catastrophic Maintenance				X

Figure 2. **'**Pavement Preservation Guidelines' chart from the 'US DoT / FHA Memo' written by David R. Geiger, Director of Asset Management.

It is clear from the definition and chart above (by David R. Geiger), that the MPPV and its design purpose-fit the Preventative Maintenance band of the Pavement Preservation model.

10.0 TOWARDS A NEW ECONOMIC MODEL

Return on Investment (ROI), is all about preserving the asset value. This is very much about recognizing and accepting a new economic model that places monetary value on a more specialist maintenance approach, with a pay back of appreciably longer pavement life and performance standards.

This is new territory for all of us and the MPPV is a prototype development to fit this role with an on-going development program to dig deeper into this economic model as the broader implications become apparent. Although more precise data can only be gathered under real-world operating conditions, the above suggests the following as reasonable broad estimates of potential cost-savings and the benefits that could logically flow out of this:

- The purchase cost of MR1 could be 50% of current alternatives. This takes into account the smaller truck chassis and pump system(s) and a preference for 'off-the-shelf' (non-proprietary) components.
- The cost of fuel and other running costs could be 40% of alternatives. This takes into account the smaller truck engine, onboard energy requirements and reduced return-to-base water replenishment requirement.
- The cost of manpower could be 30% of alternatives. This takes into account the level of automation and reduced need for waste removal/handling and even traffic management.
- The cost of water could be just 10% of alternatives. This takes into account the LV-factor when combined with the onboard cleaning/recycling systems.
- The asset utilization rate could be 500%+ of alternatives. This takes into account the multi-purpose design, the ability to have units doing different tasks in different locations, the ability to treat formerly inaccessible locations due to the small footprint, the ability to work with areas of road in need of repair on a predictive data-driven basis, and the ability to work in hot summer/shoulder season temperatures.
- The materials return rate (bitumen recycling) could be 1000%+ of alternatives. This takes into

account the (unique) ability to apply low mass/high velocity precision treatment at point-of-impact and the ability to handle waste residuals, including removal and clean-up, without sticking or coagulation.

- The BPN (friction) rate has a 100% match to standards and could be 20% better than alternatives. This takes into account the precision cutting capability of UHP/LV itself and the sophisticated design of the electronically-controlled blasthead/jewels/shroud.

11.0 SUMMARY

As Aquamax Devco have progressed the MR1 prototype programme, there have been those who have suggested that the vehicle should be very large and that the problem itself is very large. Aquamax Devco have a differing/opposing opinion when considering that the MR1 unit is designed to be a pro-active approach to roadway systems and therefore, the opinion and argument is that, the problem and it's size might be controlled.

Big equipment is a large financial investment for any company within that industry, in both equipment cost/purchase and operational overheads. Large equipment can also be very restrictive in its application as they are often 'application specific' rather than a multi-purpose tool. Aquamax Devco see, and feel, that compact multi-purpose equipment such as the MR1 could be an investment of two or three units that would be more flexible in its use, rather than becoming another 'yard queen'.