ATC Williams
GROUNDED IN DESIGN

DOWN TO EARTH

December 2012

Welcome

TAILINGS MANAGEMENT – UNDERSTANDING TAILINGS BEHAVIOUR

Tailings management is about much more than dams, stability analysis and seepage analysis. ATC Williams has always had a much more holistic approach to the subject with many hours of contemplation, testing and research being devoted to such issues as beach slopes, slurry transport and other esoteric topics. We take the view that to properly "manage" anything it is critical to have a detailed understanding of the properties of what you are trying to "manage".

With the appointment of Paul Slatter to head a new group – Rheology and Slurry Engineering – we have elevated such considerations to the level of a core activity. Paul has been actively involved in pipeline and flow process consulting and research for the past 30 years. He pioneered a new Reynolds Number design approach for yield stress materials; and the sheet flow paradigm for free surface flows of mine tailings materials.

His main expertise is the measurement, interpretation and application of slurry rheology in the engineering design of pumped pipeline systems including centrifugal pump de-rating and losses in valves and fittings, launder and open channel systems and process intensification strategies.

Paul (along with Paul Williams and Tim Fitton) recently attended the IIR 2nd Annual Slurry Pipelines Conference in Perth where he delivered one of the opening addresses – "The economics of a pipeline project" and was a participant in a panel discussion on "High concentration laminar flows".

Tim presented a paper entitled "The impact of slurry rheology on tailings transport and disposal options – case studies".

In one article in this edition of Down to Earth, Paul discusses some of the basic issues associated with assessing slurry pipeline transport.

Trevor Osborne, CEO

Establishment of Rheology & Slurry Engineering Group November 2012

Dr Paul Slatter

Dr Paul Slatter, previously Professor of Rheology and Fluid Engineering, and Director of the Rheology and Materials Processing Centre at RMIT, has joined ATC Williams to establish a Rheology & Slurry Engineering Group.

The objective of this group is to expand the capability and reach of ATC Williams in the field of rheology and slurry engineering; for ATC Williams to become a pre-eminent consultant in Australia in this field, and with the ultimate goal of an international reputation similar to that which we have built in tailings and water management.

Paul brings with him expertise in the measurement and characterisation of Slurry Rheology and its application in Engineering Design. The focus of this pioneering work in the hydrodynamic contexts of pipe flow, fittings losses, pump de-rating and free surface flows has been the production of pragmatic design approaches.

The motivation behind Paul's work has been to deliver the tools required to design, optimise and operate waste disposal systems at higher concentrations. These tools will enable industry to realise savings in costs, water and energy. Paul's work has been cited in 15 Text Books on Engineering Design relevant to Mining and Mineral Processing Plant Design.

Paul has served on numerous International Technical Committees in Rheology, Slurry Flow and Pump and Pipeline Design, and published several hundred technical papers. He is also Past President of the Australian Society of Rheology.

The combination of ATC Williams' established track record, with Paul's own established track record of excellence in research and presenting this as useable engineering design protocols, coupled with his contacts in the industry, represents an exciting expansion for the company.

In This Issue:

Paulsens Tailings Storage Facility, Paraburdoo

ATC Williams has been involved in the design and construction of five successive raises of the Tailings Storage Facility (TSF) at the Paulsens Gold Mine near Paraburdoo since 2006.

The TSF is a sidehill type facility with a crescent shaped earth embankment approximately 1 km long at the base of a low hill. The current maximum embankment height is 11.2 m and the TSF is rated as a category 2 facility of significant consequence in accordance with DMP and ANCOLD guidelines.

Sandy silt tailings are discharged at approximately 350,000 tpa with a typical solids concentration of 50% to 55%, forming a non segregating beach deposit with a slope of approximately 1%. The tailings dry and gain strength rapidly, rendering the beach suitable for the upstream method of raise construction.

Evaporation is the dominant process in the water balance, which when combined with the low discharge rate has resulted in a very small decant pond forming in the centre of the TSF, particularly since the onset of drought conditions in early 2009.

Natural surface run off is diverted around the TSF via an engineered diversion drain with rock cladding in the discharge channels at either side of the embankment. The facility is designed to accommodate storage in excess of rainfall events of at least 1:100 year AEP at all stages of operation and in keeping with best practice, an emergency spillway capable of passing extreme storm events up to 1:1000 year AEP has been incorporated in each raise construction since 2008.

To verify geotechnical design parameters and enable a detailed assessment of tailings liquefaction potential, an extensive geotechnical investigation was undertaken in 2011. This comprised investigation of the full depth of tailings deposited in the TSF, the embankment and the natural subsoil and rock profile. Investigative techniques included test pits, dynamic cone penetrometer tests, shear vane tests and electric friction cone penetrometer tests with measurement of pore pressure (CPTU).

In addition, shear wave profiling was undertaken through the tailings deposit by seismic cone penetration testing (SCPT) and undisturbed samples of tailings were recovered using a Mostap discrete sampler. The test area extended up to 180 m from the embankment crest.

Geotechnical laboratory tests were performed on most of the samples recovered from the deposited tailings and specialised testing was undertaken by ATC Williams on a sample of 'fresh" tailings slurry to verify tailings properties and calibrate beach slope models. Geochemical characterisation tests were also performed on tailings samples and samples of waste rock which could potentially be used as cover material during closure of the TSF.

Interpretation of the investigation results indicated a distinct pattern of reducing shear strength, shear wave velocity and density and increasing moisture content and compressibility with distance from the embankment.

This enabled an assessment of the maximum extent to which future embankment raises could be successfully constructed.

A detailed liquefaction analysis was carried out which assessed potential for liquefaction on the basis of tailings grading and plasticity, CPT tip resistance and shear wave velocity profile.

Design earthquake conditions were selected in accordance with ANCOLD guidelines and appropriate corrections were made to ground acceleration coefficients to account for the presence of the tailings profile above the rock surface.

The analysis concluded that the risk of liquefaction induced damage is very low and within acceptable limits since:

- Liquefaction will not occur under design operating conditions.
- In the vicinity of the embankment, the lower part of the deposit (approximately 3 m thick) could potentially liquefy but only under extremely adverse conditions of maximum design earthquake (1:1000 AEP) coupled with full saturation or flooding of the TSF (1:800 AEP rainfall).
- If liquefaction of the lower part of the deposit did occur under such conditions, the estimated post liquefaction shear strength in the lower tailings is sufficient to maintain satisfactory factors of safety against embankment failure. The estimated post liquefaction shear strength of the material approximated to a Su_{liq}/σ_{vo}' ratio of 0.04.

Tailings Pipeline Design

The tailings stream from a mining operation is often in a slurry form – a mixture of solids and water – and is pumped from the processing plant to the tailings disposal area.

Essentially the problem resolves to predicting the effect that solid particles have as the mixture flows in the pipe.

From a fundamental perspective, this is an extremely complex problem, and has so far defied rigorous physical analysis.

When Albert Einstein began his PhD studies, there were only two remaining unsolved problems in classical physics; the wave/particle nature of matter, and fluid turbulence. He very wisely chose the easier option – the first one – and fluid turbulence remains to this day the last unsolved problems in classical physics! Our "understanding" of fluid flow is empirical and experimental test work rests at the heart of solutions for the design task.

Idealistically, we can divide the effect that the solids has into two principal areas. Coarse solids will tend to settle when mixed with water, and will need to be suspended by a degree of turbulence in order to be transported along the pipe.

On the other hand, small non-settling particles (fines) will not require any mechanism to remain suspended during transport, but will modify the viscous characteristics – called rheology – of the carrier fluid. These two cases form the idealised extremes, and are discussed below.

Transport of coarse, settleable solids

The behaviour of coarse, settleable solids during pipeline transport is shown in **Figure 1** as the blue line. The carrier fluid only is shown as the black line.

At very high flow rates and pipe velocities – on the right hand side of **Figure 1** – the blue and black are parallel and almost asymptotic.

This is because all of the coarse solids are suspended by the high degree of turbulence associated with these high velocities, the concentration distribution is close to uniform, and a pseudo-homogeneous state is achieved.

As the velocity is decreased, and we move to the left on **Figure 1** , we see a change in behaviour away from that of the carrier fluid only, and the blue line takes on the distinctive hook-shape which is so characteristic of these flows.

This is because the degree of turbulence reduces, and particles begin to settle on the pipe invert.

A bed forms and begins to occlude the available flow area, eventually causing an increase in pressure gradient.

The deposition velocity V_{sm} is recorded as the bulk velocity at which a stationary bed begins to form. It is not advisable to operate a pipeline below this velocity as pipe blockage can occur.

Transport of fine non-settling solids

The behaviour of fine non-settling solids during pipeline transport is shown in **Figure 2.**

The viscous characteristics or rheology of the mixture is quite different from the carrier fluid, and – for most mine tailings – is typified by a yield stress.

The presence of a yield stress indicates that the mixture has some solid as well as liquid characteristics. This gives rise to the ordinate offset shown in **Figure 2**, below which the mixture will not flow, as the applied stress is less than the yield stress.

Figure 2 also shows that a significant region of laminar flow can be expected, due to the increased rheology that the mixture now possesses.

Transport of broad particle size distribution slurries

The above approaches represent the two extremes of the spectrum of particle sizes, and most applications lie between these two. To analyse the flow behaviour of these broader particle size ranges, a combination of the above two approaches is used.

Although beyond the scope of this article, suffice it to say that both the rheology of the fine particles, as well as the settling characteristics of the coarse particles, is taken into account.

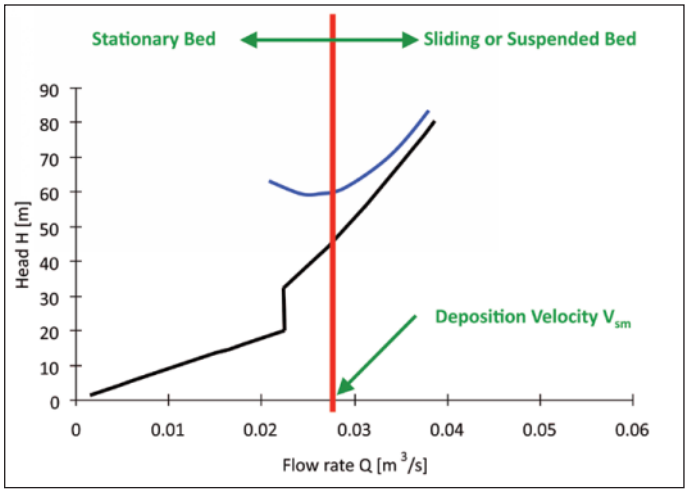

Figure 1: Pipeline Flow Behaviour of Coarse Settleable Solids

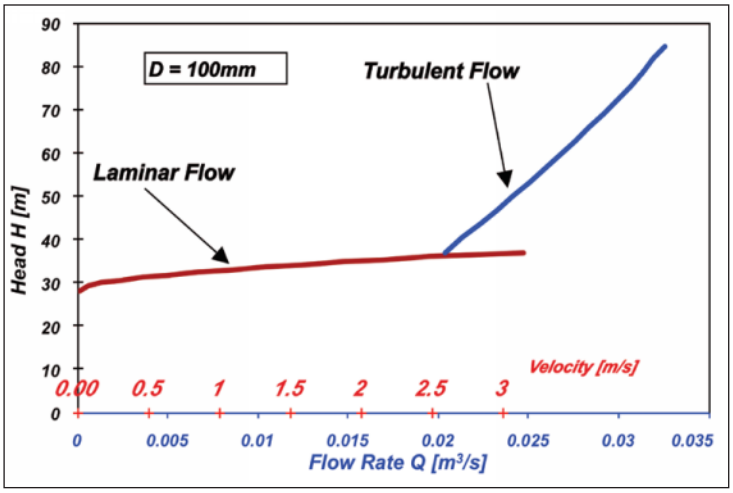

Figure 2: Pipeline Flow Behaviour of Fine Non-Settling Solids

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Our Services

ATC Williams specialises in consulting engineering services for the construction, infrastructure, mining and resources industries.

Our three business lines, Australian Tailings Consultants, Geotechnical, and Water, provide a range of services in their respective business sector.

The scope of our capability is best reflected in the following core services:

- tailings management
- dams
- geotechnical investigations
- foundation engineering
- retention and slope stability
- acid sulfate soils and acid rock drainage management
- water management
- groundwater and hydrogeology
- mine rehabilitation and closure
- laboratory testing
- slurry transport

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CONFERENCES & PUBLICATIONS

Last month **Paul Slatter**, **Tim Fitton** and **Paul Williams** attended the *2nd Slurry Pipeline Summit in Perth.*

Both Paul Slatter [pictured] and Tim presented papers at the conference, with Tim co-writing his paper with Arash Roshdieh. Paul Slatter also joined a panel of world experts to discuss laminar flow in pipelines. This conference provided us with our first opportunity to publicly present ATC Williams' new **Rheology and Slurry Engineering Group**.

ANCOLD Workshop

This was held in Perth on 24th October.

ATC Williams was represented by **Keith Seddon** who gave a presentation *"Cone Penetrometer Results in Tailings"*, **Mark Dillon, Alex Van Koersveld** and **Muhunthan Arunasalam**.

UDIA 2012 Awards

On Saturday 1st September ATCW Perth was invited to attend the *UDIA Awards for Excellence Gala Dinner.* This was in recognition of their involvement as consultants for the Fairlanes Perth project.

Perth Office representatives at the UDIA 2012 Awards for Excellence, **John Leavy** (left) and **Charles Vuillier.**

Hydrology & Water Symposium

Jessica Ward attended the *Hydrology and Water Resource Symposium (HWRS)*, Sydney in November. A particular focus of the symposium was on the work which has been undertaken with respect to the revision of Australian Rainfall and Runoff guidelines.

QLD Water Symposium

Vadivu Verakumaran attended the *Queensland Water Symposium* on 27 and 28th October, 2012. The symposium topics included hydrology, hydraulics, floodplain management, water quality, irrigation, catchment and stormwater management, groundwater, and coastal engineering.

Africa Downunder

In August, **Charles Vuillier** and Perth staff members participated in the Perth Expo.

AGS Symposium

Allan Watson and **Siamak Pahlevanzadeh** attended the Australian Geomechanics Society One Day Symposium in October, entitled *Reducing CAPEX by Managing Geotechnical Risks on Projects*.

Core subjects included:

- *Reducing CAPEX by Adopting Alternative Solutions for Projects*
- *Managing Geotechnical Risk in The Mining Industry*
- *Good Practice in Site Investigation and Design Process*
- *Integration of the Geotechnical Known and Unknowns into Reducing Project CAPEX*

Mine Tailings 2012 Conference

Allan Watson presented a paper to the *Mine Tailings 2012* conference entitled *Integrated Tailings and Water Management.*

Brisbane Workshops

Elisabeth Boczek attended the following:

- *ACG Designing for Closure: Appropriate Design Criteria and Methods of Analysis Workshop*, 24 September
- *ACG Use of Geochemical Data in Addressing Environmental Problems in the Mining Industry Workshop*, 23 September.

Christian Lisle attended the following:

- *Prevention is better than cure: the Causes, Consequences and Control of Soil Erosion in Mine Rehabilitation* (22 September).

The workshop involved presentations and worked examples about erosion on mine and landfill sites. The presentations went into depth about all aspects of erosion, including causes, erosion process, modelling of erosion, risks assessment and control measures to reduce erosion from occurring in the first instance rather than fixing erosion problems after they occur.

- *Geo-synthetics for Success (GSE Environmental) Technical seminar (August)*. Provided several technical presentations and case studies relating to the uses of GCL, Geo-membranes and Geo grids in mining and landfill applications. Demonstrations of spark testing as well as samples of the various materials were made available.

STAFF NEWS

Tim Newman recently graduated with a Masters Degree in Engineering Science (Geotechnical Engineering).

David Nixon Retires

After a long and distinguished service on the Board of ATC Williams, **David Nixon** resigned from his position as a Director. David was appointed to the Board in April 2005 and his valuable contribution over the past 7 years has been greatly appreciated. ATCW sincerely thanks David for his commitment and service during his period as a Director.

Melbourne and Brisbane Premises

Due to continued growth, the Melbourne and Brisbane offices have been renovated and extended. In Melbourne ATCW now occupies the entire lower floor and has space to cater for more than the current 50 staff. In Brisbane the office has doubled in size from 10 to 20 and more space will be needed soon.