Institution: Glasgow Caledonian University

Unit of Assessment: 15 General Engineering

Title of case study: Innovative Tunnel Backfill by Pneumatic Conveying of Dry Particulate Materials.

1. Summary of the impact (indicative maximum 100 words)

Research at GCU led to a novel method for backfilling pipeline tunnels providing the ability to fill tunnels three times more quickly than the traditional method resulting in a cost saving of £1.5M on a single project. This approach is now best practice at Murphy Pipelines Ltd (MPL) and features in current tenders to a value of £30M. The change in fill material lowered the carbon footprint by 5000 tonnes in a CEEQUAL award winning project, in addition, the removable fill material allows the recycling and re-use of tunnels, adding to the assets of the company and reducing costs.

2. Underpinning research (indicative maximum 500 words)

Research on pneumatic conveying by experiment and simulation has been on-going since the foundation of the Centre for Industrial Bulk Solids Handling at GCU in 1990 and is currently led by Professor Don McGlinchey. Pneumatic conveying as a means to transport particulate materials is conceptually very simple; gas, usually air, is set in motion with sufficient energy to entrain the particles and carry them along in the flow stream. The industrial use of this technology is long established and applied across a range of sectors; power generation, plastics, bulk chemicals, and pharmaceuticals but still relies significantly on empirical and heuristic approaches to improve the efficiency of pneumatic conveying systems. The principle task when designing or optimising pneumatic conveying systems is the determination of the system operating point in terms of gas mass flow rate and overall line pressure drop to achieve a desired throughput of particulate solids. Many correlations exist in the literature to predict system operation; however, they are individually limited in application. The research programme undertaken at GCU beginning in the 1990s and continuing to date, resulted from the desire improve the design method. The early research leaders were Dr David Mason, Prof Avi Levy and the late Prof Predrag Marjanovic who developed a general framework for simulation and modelling gas-solids flow. [1-3]. This work developed a one dimensional computational Eulerian two – phase flow of interdisperse continuum for general flow in straight pipelines, with other pipeline features such as bends requiring to be modelled empirically. McGlinchey and co-workers have refined the simulation methods and improved the investigation of the detail of flow features, [4-5], by using either granular kinetic theory or the discrete element method to model the solids in combination with traditional computational fluid dynamics to create three dimensional models of pipelines and features. Pneumatic conveying systems can be modelled by a combination of the techniques noted above. The research and applied knowledge base at GCU were recognised by MPL as a vital factor in developing a novel tunnel backfill system. To complete the final system design for Murphy Pipeline Ltd, GCU carried out both simulations and experimental characterisation based on methods developed at GCU using an industrial scale pneumatic conveying research facility. This facility has been used for numerous research projects including the conveying of sand and sand like material, and was suitable for scaling to the duty required by MPL. Output of GCU research is based on a computational fluid dynamics approach to simulating pneumatic conveying of dry particulate solids with experimental validation and was shown to have good agreement in the dilute phase region of operation proposed for the system design for MPL.

3. References to the research (indicative maximum of six references)

1. Mason, D.J. Marjanovic, P. and Levy, A., "A Simulation System for Pneumatic Conveying Systems", Powder Technology, Vol. , pp. - , 1997.
2. Mason, D.J., Levy, A., “A comparison of one-dimensional and three dimensional models for the simulation of gas-solids transport systems.”, Applied Mathematical Modelling, v22, pp517-532, 1998.

3. Mason, D.J., Levy, A. “A model for non-suspension gas-solids flow of fine powders in pipes.”, International Journal of Multiphase Flow, v27, pp415-435, 2001
4. Xiang, J., McGlinchey, D., "Numerical simulation of particle motion in dense phase pneumatic conveying", Granular Matter, Vol. 6, Nos. 2-3, pp 167-172, 2004
5. McGlinchey, D., Cowell, A., Knight, E.A., Pugh, J.R., Mason, A., Foster, B., "Bend Pressure Drop Predictions using the Euler-Euler Model in Dense Phase Pneumatic Conveying ", Particulate Science and Technology, Volume 25, Number 6, pp 495-506, 2007.

4. Details of the impact (indicative maximum 750 words)

The Harefield to Southall Gas Pipeline in London was a major civil engineering project undertaken by murphy Pipeline Ltd involving the design and construction of 18km x 1220mm diameter gas pipeline and connection into the existing network. The pipeline was laid in tunnels under major arterial roads, railways (including London Underground), water courses and the Grand Union Canal

In summary, the benefits for MPL of using the technology developed from GCU research were:

- Savings of £1.5M on one project
- Environmental impact – A CEEQUAL Outstanding Achievement Award 2011 for Waste Management. (Low carbon footprint, a reduction of 5000 tonnes on one project)
- Establish best practice in the sector
- Provide competitive contract tenders to a value of £30M for projects worldwide.

The backfill technique developed using the research and design at GCU was first used in tunnels in a project to meet rising gas demand in West London, where Murphy Pipelines Ltd was contracted by National Grid to construct an underground, high-pressure, steel pipeline between Harefield and Southall. As well as providing the additional peak capacity necessary to meet licence conditions, the pipeline strengthens security of supply for customers in West London by ending their reliance on a single source of high-pressure gas supply.

In order to meet engineering and safety requirements Murphy Pipelines Ltd (MPL) had to find a way to provide mechanical support for a gas pipeline running along underground tunnels from Harefield to Southall comprising: 18.2 km of 1220mm diameter gas pipeline, 3 segmental tunnels approx 2.225km and 8 pipejacks approx 0.935km

Conventional methods for support and backfilling were impractical and time consuming, therefore pneumatically conveying a dry particulate material was considered.

The research and expertise in pneumatic conveying residing in Glasgow Caledonian University, as highlighted on the website www.particulatesolidshandling.com, led MPL to commission GCU to undertake an initial feasibility study starting in May 2006 involving simulation of a proposed conveying system, followed by pneumatic conveying and wear assessment trials in our solids handling and pneumatic conveying test labs, finishing in September 2007. GCU provided unique conveying characteristics for a range of conveying configurations and distances allowing the most appropriate particulate material and conveying technology to be selected.

Initially, estimates of pipe bore and gas flow rates were made for required conveying distances by scaling published data for a similar material and by use of a computer model developed at GCU which demonstrated the potential of the method to meet the required duty.

A pneumatic conveying system at GCU was successfully used to test the performance of potential backfill materials through different pipeline configurations.

An established scaling procedure was carried out on the data from experimentally determined conveying characteristics for a change in pipeline length and a change in pipe bore. Conveying

characteristics were generated for seven different design configurations of varying length and pipe bore. A particular design configuration was highlighted in discussions with Murphy Pipelines as being the most likely or favoured design.

The application of GCU's research was challenging due to the complexity of the design and operation of systems; for example, very regular changes in pipeline lengths as the tunnel is filled will result in dramatic changes to the optimal operating point and the likelihood of pipeline blockages and failure of operations is significant if the system is not correctly designed and operated.

Based on the GCU design parameters and recommendations, MPL commissioned the manufacture of a tunnel backfill system from Aptech Ltd, a specialist in the design, supply and installation of particulate solids handling equipment based in Leicestershire.

The traditional method used for tunnel filling by cement grouting but this comes at a high price environmentally and financially. Following the work at GCU dry sand was used to fill the large diameter tunnels on the project. As well as being cheaper to buy and work with, the embodied carbon associated with its production is 60 times less than that of grout. A recycled glass product called EcoSand was also used as an innovative and more sustainable alternative to sand. The carbon saving was equivalent to that of sand, but with the added benefit of making use of a waste product instead of a non-renewable resource. Being quicker to install, this technology represented a 10-week saving on the project programme, as well as saving 5,000 tonnes of embodied carbon. This, in part, made the Harefield to Southall Gas Pipeline Project a Winner of a CEEQUAL Outstanding Achievement Award 2011 for Waste Management. The gas pipeline became operational in December 2009.

5. Sources to corroborate the impact (indicative maximum of 10 references)

Murphy Pipelines
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Tel: 020 7267 4366
http://www.ceequal.co.uk/awards_066.htm
http://www.murphygroup.co.uk/AboutMurphy/Awards/default.asp?id=133
http://www.ceequal.com/pressrelease_150311.htm
http://www.particulatesolidshandling.com