Keeping pipelines on the level: Dr Bassem Youssef

As part of his PhD study, Dr Bassem Youssef, who is now employed at Atteris as a project engineer, developed a unique pipeline on-bottom stability simulation program, which won the Australian Gas Innovation Award Commendation in 2012. *The Australian Pipeliner* spoke with Dr Youssef to find out more about his research and why it is so important for offshore pipelines.

Prior to undertaking his PhD at the University of Western Australia (UWA), Dr Youssef attended the Suez Canal University in Egypt, completing a bachelor degree in civil engineering in May 2000, and receiving a masters' degree in May 2006 for his research on the structural stability design of hydraulic regulators and navigation locks crossing the river Nile.

"During this time, I also gained great experience from working as a marine structural engineer at an engineering consultancy in Cairo, responsible for designing harbour breakwaters and marine wharfs," says Dr Youssef.

In September 2008, Dr Youssef commenced his PhD at UWA's Centre for Offshore Foundation Systems, completing it in May 2012 after "approximately three years and three months of hard, but enjoyable work".

Dr Youssef's PhD research dealt with the on-bottom stability analysis of offshore pipelines under the action of wave and current loading.

"My thesis title was *The Integrated Stability Analysis of Offshore Pipelines*," says Dr Youssef. "It detailed how hydrodynamic load modelling, pipe-soil interaction modelling and the coupling effect between the hydrodynamic load and the pipe-soil interaction can be properly considered using deterministic and statistical analysis methods.

"The motivation of my PhD research was to develop an integrated pipeline on-bottom stability analysis program and design methodology, and to use it to achieve a better understanding of hydrodynamic pipe-soil interaction."

In May 2012, after spending approximately six months as a research associate at the UWA's Center for Offshore Foundation Systems, Dr Youssef joined Atteris, allowing him to continue his work with offshore pipelines.

Dr Bassem Youssef with the 2012 Australian Gas Innovation Commendation Award.

> Pipeline shore crossing design is one of the areas of the pipeline industry that I am interested in working in.

"Atteris offers pipeline engineering solutions to offshore development projects, from the early concept phase through to the detailed design engineering phase, including subsequent field engineering and project management support," explains Dr Youssef. "My responsibilities at Atteris include undertaking engineering design work of subsea pipelines and the development of Atteris' pipeline design software packages."

Here, Dr Youssef shares details of his award-winning research with *The Australian Pipeliner*, his outlook on future developments in this area, as well as his own industry aspirations.

Why has it been so important to develop studies into the stabilisation of large diameter subsea pipelines?

On-bottom stability analysis of offshore pipelines is a complicated interaction between three components: the hydrodynamic loads, the pipeline and the supporting soil. In the case of large diameter gas pipelines, which are typical in the North West Shelf of WA, on-bottom stability analysis is one of the key features of the design.

The analysis is essential to ensure that a pipeline is stable when exposed to extreme wave and current loadings. Secondary stabilisation of subsea pipelines can contribute a large capital cost component to any project, as well as significant schedule implications. Therefore, accurate and comprehensive pipeline on-bottom stability studies should be conducted to ensure that the pipeline will be designed economically and will operate safely under harsh environmental conditions without the use of unnecessary secondary stabilisations.

> Another important area in offshore pipeline design is lateral and upheaval pipeline buckling in areas where pipelines operate at higher temperatures and pressures.

Which stabilisation methods are the most effective for offshore pipelines offshore WA? And why is this so?

Offshore pipeline stability requirements vary from project to project and from one site to another. There are many factors influencing pipeline stabilisation design, such as the pipeline's diameter, self-weight and its route. Other on-bottom stability design factors mainly relate to the pipeline route selection, such as the water depth in which the pipeline will be installed, the seabed geotechnical conditions, and the expected hydrodynamic activity along the selected pipeline route.

In most cases, pipeline weight is provided by the pipeline steel wall and the concrete weight coating. If the pipeline weight is insufficient to meet the on-bottom stability requirements, the design must consider improving the pipeline stability by increasing the weight or by using one of the secondary stabilisation methods. High-density concrete weight coating (density of up to 3,400 kg per cubic metres) with reasonable concrete cover thickness is usually used as the first option in achieving pipeline stability requirements. Laying the pipeline in a trench, for example, will provide sheltering to the pipeline from the acting wave and current hydrodynamic loads, and hence improves the pipeline stability.

Post-trenching a large diameter pipeline has been performed once in the North West Shelf in the early 1980s via ploughing. It has been recognised since that the »

« unpredictable nature of the geotechnical conditions along pipeline routes in the North West Shelf, due to the presence of cemented layers and large areas of shallow calcareous rock, do not favour this method for large diameter pipelines. The risk of not achieving the required trench depth after pipeline installation is simply too high.

What other stabilisation methods are available for offshore pipelines?

There are many stabilisation methods that a pipeline engineer can use to improve pipeline stability. However, among the most common stabilisation methods are rock dumping, gravity anchors, rock bolts and trenching (pre- or post-pipelay).

Most of the pipeline secondary stabilisation methods are costly, time consuming and have construction implications when compared with the concrete weight coating option. In the case of rock dumping, for example, a relatively large quantity of quarry rock must be transported from inland quarries to the pipeline location. Another pipeline stabilisation solution is to place gravity anchors along the pipeline at discrete spacing. A typical example of a gravity anchor comprises of a high-density concrete saddle placed on top of the pipeline at predetermined locations.

What are some other design issues that offshore pipeline engineers are faced with, particularly with regard to the conditions imposed by WA's offshore conditions?

The seabed material of many offshore regions of WA, particularly the North West Shelf region, are primarily composed of calcite and aragonite derived from the skeletal remains of marine organisms, known as calcareous soils. The high crushability and compressibility of the calcareous soils make this seabed type much weaker in resisting loads than non-calcareous soils that have the same particle size distribution. Therefore, specific calculations and pipe-soil interaction models are required to accurately simulate and capture such soil behaviour.

Moreover, calcareous soils have a high erodibility index, which makes the seabed unstable when subjected to high near-seabed water velocity. The erodibility of the seabed can cause local scour holes underneath the pipeline and hence change the lateral resistance provided by the seabed. In the situation where scour occurs immediately below the pipeline, the hydrodynamic loads will be reduced and eventually the pipeline may sag into the scour hole.

Atteris has been involved in physical testing of pipeline models on calcareous seabed. The tests were conducted in the large o-tube facility at UWA. The test results have highlighted that the seabed erosion and scour hole formation underneath the pipeline may lead to pipe self-embedment and consequently provide greater stability to the pipeline. This argument is also supported by remotely operated vehicle footage of many pipelines offshore of WA where the pipelines are found partially, and sometime fully, buried in the seabed.

The available design guidelines and recommended practices have simplified the pipeline on-bottom stability problem by neglecting the hydrodynamic-soil interaction and the erodibility of the seabed material. Certainly, considering the erodibility of the seabed in the pipeline stability design will lead to achieve more reliable and economic pipeline stability designs.

Another important area in offshore pipeline design is lateral and upheaval pipeline buckling in areas where pipelines operate at higher temperatures and pressures. Internal pipeline pressure and temperature often reach higher values during start-up operations than those prevalent during installation/backfilling of the line. Such an increase in temperature and pressure may cause the pipeline to expand during the start-up and operation cycles. An accurate pipe-soil interaction model is required to predict the pipeline buckling behaviour and to achieve reliable and accurate buckling design.

Are there any particular programs you use in your designs of offshore pipelines?

Atteris uses commercial finite element programs such as ABAQUS, AutoPIPE and SAGE Profile-3D to perform specific offshore pipeline designs. Moreover, Atteris has developed its own three-dimensional pipeline modelling program, CORUS-3D, to perform dynamic pipeline simulations under the action of storm loading.

The program complies with the recommended practice (DNV RP-F109) requirements for dynamic lateral stability assessment. CORUS-3D generates full sea-state storm realisations and implements accurate pipe-soil interaction modelling. CORUS-3D uses the commercial Finite Element package ABAQUS as its user interface, which allows COURUS-3D pipeline simulation results to be reviewed

The available design guidelines and recommended practices have simplified the pipeline on-bottom stability problem by neglecting the hydrodynamic-soil interaction and the erodibility of the seabed material.

through the ABAQUS main user interface window. Numerous simulations have been undertaken and compared to available pipeline physical modelling results and pipeline benchmark cases. This benchmarking exercise has been used to validate CORUS-3D and demonstrate its ability to accurately perform such complex pipeline simulations.

Post-trenching a large diameter pipeline has been performed once in the North West Shelf in the early 1980s via ploughing.

Are there any plans to develop software that will assist in the development of effective stabilisation methods of offshore pipelines?

I believe there are still some gaps in the pipeline stability design guidelines that need to be covered in order to reduce the inaccuracy and conservatism in the design and to achieve more economic and reliable pipeline designs.

In my opinion, the ultimate goal of any new software package is to perform accurate modelling and to represent the actual scenario. Certainly, I am happy to assist in implementing my understanding of seabed scour and hydrodynamic-pipe-soil interaction into softwares and models that the pipeline industry will use in assessing the pipeline stability.

What other areas of the pipeline industry are you interested in working in?

Pipeline shore crossing design is one of the areas of the pipeline industry that I am interested in working in. The shore crossing design is a combination of site selection and design activities required to maintain pipeline stability and integrity while minimising impact to the environment and the adjacent property or facilities.

Challenges facing the pipeline engineer during the shore crossing design include site selection, design basis definition, pipeline stability analyses, operational requirements and construction method definition. This also includes how to maintain significant construction cost reduction and operational reliability of the pipeline system. P