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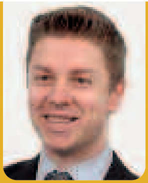
Deep impact: the future of physical modelling

Hydrolink

DEEP IMPACT: THE FUTURE OF PHYSICAL MODELLING

BY DAVID TODD, JAMES SUTHERLAND, JOHN HARRIS & RICHARD WHITEHOUSE

HR Wallingford's Fast Flow Facility, one of the world's largest marine test facilities, was opened in October 2014. Now, one year on, this versatile facility is setting the pace in physical modelling.



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Professor Richard Whitehouse **is a Chartered Geographer and Technical Director at HR Wallingford with responsibility for the Fast Flow Facility. His main focus is on sediment transport and geomorphology in river, estuarine, coastal and subsea environments.**

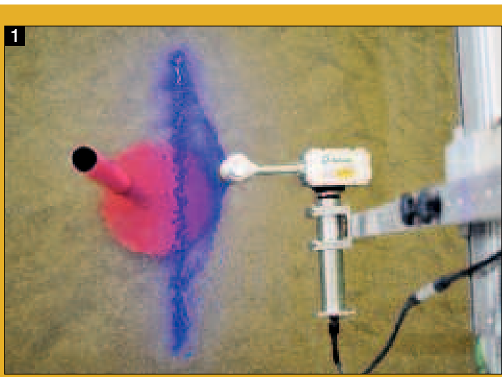
Physical modelling has been a mainstay of HR Wallingford since the laboratory was established in the 1940s. In the beginning, waves were made in a large, outdoor basin by two men pushing a wave paddle between two points and a foreman with a stopwatch blowing a whistle to maintain the correct period. As you can imagine, tests were short in duration!

Almost 70 years later, enter the Fast Flow Facility. This new standard in physical modelling was developed to take physical modelling at HR Wallingford into the future. An extremely versatile facility, the Fast Flow Facility enables the production of fast currents and large waves in deep water, allowing physical model tests to be run at larger scales than would otherwise have been possible – deeper, faster, bigger. The first year of operation has seen a suite of commercial operations undertaken investigating novel scour protection, tidal turbine systems and, most recently, extensive testing of a number of offshore wind related structures for Danish Oil and Natural Gas (DONG) Energy. In addition to this, the facility has been home to exciting collaborative research with world-leading academics and private, company-funded research designed to keep HR Wallingford at the cutting edge of scientific developments.

Physical modelling has developed greatly during HR Wallingford's history, but no change has been as great as that seen in the last 25 years with the advent of personal computers, laser and acoustic instrumentation. Fifteen years ago, scour experiments relied upon one or more scientists moving touch-sensitive bed profilers around a structure to make measurements of scour development. This method allowed 8 radials of approximately 125 points to be made in a 30 minute period – a total of approximately 1 000 points per half hour. More recently, HR Wallingford has made use of terrestrial laser scanning systems in our large wave basins to allow greater, more repeatable coverage that is less subject to human error. However, this technique requires the facility to be free from water as reflections from water surfaces cause errors in the measurements. This technique, therefore, while perfect for tasks like identification of breakwater armour movement, was not suitable for the new Fast Flow Facility.

The 4 m width of the Fast Flow Facility main channel allowed us to install a fully programmable x-y traverser system, which moves instruments up and down the flume to precisely known locations. We now deploy underwater laser scanners within the flume that are capable of recording approximately five million points with sub-millimetre accuracy in half an hour - five thousand times what we were capable of just 15 years ago. The laser scanners are able to cover a large area with good temporal resolution, providing data that is comprehensive in its coverage, representative of the experiment being undertaken, repeatable (as the exact position of each point is known) and less subject to human error. In addition, as these laser scanners are fully submersible, there is no need to stop testing or drain the facility as scans can be undertaken while experiments are ongoing.

Bathymetry measurements are not the only aspect of physical modelling that has changed drastically in the last 25 years. Flow profiles used to be restricted to a few points in the water column and were measured using propeller meters. However, with the acoustics revolution resulting in instruments such as the Nortek High Resolution Aquadopp – capable of bins as small as 7 mm and sampling rates of up to 8Hz – flow profiles can now be estimated across most of the water column (with blanking distances immediately below the instrument and immediately above the bed) both quickly and accurately.
The areas immediately sub-surface or above the bed can be sampled using the Nortek



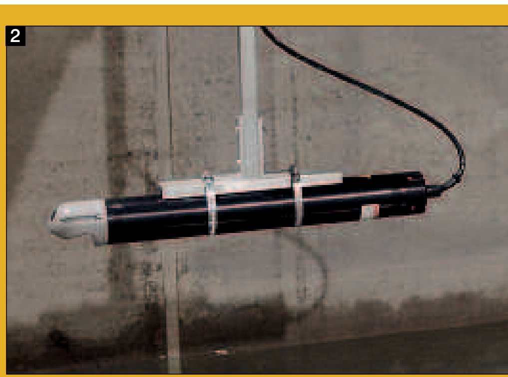


Figure 1 - Underwater laser scanner profiling the bathymetry around a suction bucket pile

Figure 2 - Aquadopp installed in Fast Flow Facility

Figure 3 - Wave gauges, suction bucket pile and Vectrino (on right) prior to a scour test

Figure 4 - Vectrino II ADV deployed in the Fast Flow Facility

Vectrino II – an acoustic instrument capable of measuring the three components of velocity in a 30 mm section at 1 mm intervals down to approximately 3 mm above the bed at sampling rates of up to 100 Hz. Such high sampling rates allow the investigation of turbulence and wave characteristics.

These instruments have all been utilised successfully during the first year of operation in the flume. The most recent commercial work, undertaken for offshore wind developer DONG Energy, has involved exploring alternatives to the traditional monopile foundation. Well understood and heavily utilised in shallower near-shore regions, as offshore wind moves into deeper water, larger monopiles are required which must be installed at greater depths. These factors are resulting in monopiles slowly becoming less viable as foundation structures. Because of this, developers are designing and testing alternative foundations in order to reduce costs and keep offshore wind competitive within the energy market place.

Even in deeper water, offshore wind farms are often sited in areas affected by strong tidal currents in combination with steep, near breaking waves. These conditions can result in scour, posing a risk to the stability of turbine foundations, cables and cable crossings, while protection and mitigation works come at a high cost. Optimisation works for scour protection are still developing. Often, scour protection designs have been tested with dominant wave conditions only due to the limitations of the test facilities. To cover real exposure conditions for the North and Irish seas for example, the ability of the Fast Flow Facility to reproduce design conditions of combined waves and currents under true live bed conditions, with mobile sediment and at a large scale is of significant importance for an optimised and yet robust scour protection design.

For deep water applications, a new suction bucket jacket foundation design has been refined by DONG Energy as an alternative to the traditional monopile. This new structure required physical model testing to determine how the structure interacts with, and impacts upon, the local hydrodynamic conditions and the surrounding seabed. HR Wallingford has been carrying out physical model testing of scour response to optimise the design of the suction bucket jacket and mitigate scour development.

Key to this testing was the ability to run both fixed and live bed conditions in the Fast Flow Facility, allowing investigations into the potential depth of scour and the stability of rock armour of various sizes and gradings. Gathering information on the size and extent of protection that is required under differing hydrodynamic conditions is vital to the survivability of the scour protection.

An underwater laser scanner was utilised to measure the bathymetry before, during and after each test, providing details of the development of scour both temporally and in extent. Current profiles, collected using the Aquadopp HR profiler and Vectrino II Acoustic Doppler Velocimeter (ADVs) have provided a record of the hydrodynamic conditions run in the facility. Twin-wire wave probes located at different points along the flume provided detailed wave spectra, while a High Definition (HD) underwater video camera was used to provide real-time visual feedback of scour development and armour stability.

Physical modelling techniques have changed markedly over the last quarter century with the advent of new measurement capabilities allowing greater coverage of test areas, both temporally and spatially. The Fast Flow Facility was built to be the future of physical modelling at HR Wallingford, with its first year proving a huge success as it utilises the latest technology to deliver large-scale commercial and research projects. Progress within the facility also shows no sign of slowing, with the in-house development team set to release a set of rapid calibration wave probes and a jacking system for the wave paddle in the next few months. ■