DHI CASE STORY

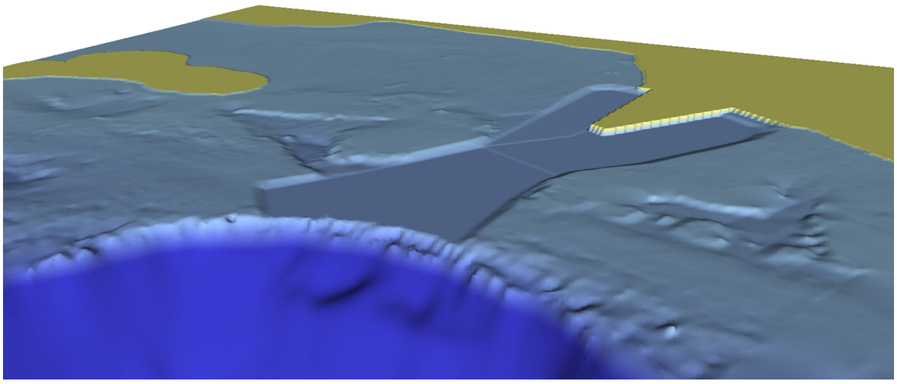
MITIGATING HURRICANE STORM DAMAGE AT FALMOUTH CRUISE TERMINAL

A multi-modelling approach for wave transformation over a highly complex bathymetry

Jamaica's north coast became home to a new cruise terminal in 2011. The Falmouth Terminal includes an approximate 760-metre quay for the reception of two cruise liners carrying a total of 10,000 passengers. The facility is intended to welcome tourists to the island for many years to come. However, the extreme hurricane events that occur in the region pose a flood threat to the terminal buildings. The client needed to establish whether there was a risk of flooding of the terminal buildings caused by wave overtopping during the worst of Jamaica's storms. If so, they needed to know how to protect the existing structures against the extreme waves.

STEEP DROPS AND HIGH WAVES

Calculations were complicated by the highly complex bathymetry (water depth conditions). The terminal is built on a very shallow reef with water depth of just a few metres. At the reef edge, approximately 1 kilometre from the shoreline, the water depth drops steeply to several hundred metres. To allow access for the massive cruise ships, an access channel was dredged from the reef edge to the terminal and its two berths on either side of the pier. The resulting bathymetry together with the high waves caused by tropical storms made calculation of the potential wave conditions and their impact on the terminal a highly complex and challenging task.



Model representation of the bathymetry of the seafloor at Falmouth cruise terminal, showing the steep drop at the reef edge as well as the dredged access channel.

SUMMARY

CLIENT

E. Pihl & Son A.S., Denmark

CHALLENGE

To protect cruise terminal buildings even during extreme hurricane events in a highly complex bathymetric setting. That required evaluating precisely the wave conditions, potential flooding of the terminal buildings as well as possible protective structures.

SOLUTION

An innovative combination of

- three different numerical wave models,
- physical model tests and
- literature findings

allowed for a comprehensive modelling and understanding of wave transformation and overtopping at the terminal pier.

VALUE

- Identification of the most effective wave screen design
- Protection of the terminal building and structures even during extreme hurricane conditions
- An accurate, reliable, cost-effective and innovative multi-modelling solution

LOCATION / COUNTRY

Falmouth, Jamaica

A COMBINATION OF MODELS FOR A HIGHLY COMPLEX PROBLEM

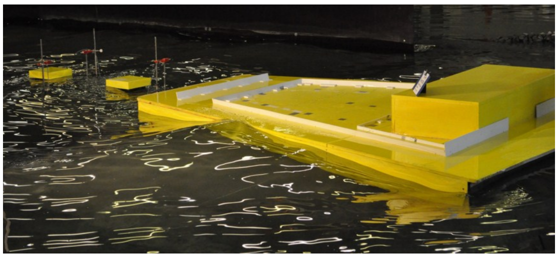
There was no single existing wave model that could be adopted to deliver all the required information. Therefore, DHI - called in by the client following successes on earlier projects - took an innovative approach by combining the strengths of three different numerical wave models as well as physical modelling and findings from literature. Based on our results, the most effective wave screen design was selected.

The tourist facilities at the Falmouth cruise terminal comprise a small town of buildings that are adapted to the Georgian architecture of the 18th century, which is characteristic for the historic houses in Falmouth. It was elected "Port of the Year 2011" among 89 ports worldwide.

DETERMINING THE MOST EXTREME WAVE CONDITIONS AT THE PIER

DHI combined the strengths of three of our models to solve this challenging task.

- MIKE 21 PMS and MIKE 21 BW reproduced the energy dissipation due to wave breaking as well as the *wave refraction and wave diffraction* (see Glossary).
- The CFD model NS3 studied the reduction in wave height due to wave breaking over the different depths. This third model was adopted because model settings for MIKE 21 PMS, normally used for typical coastal applications, could not be assumed in this case due to the very deep seabed slope, the shallow waters along the channel and the excessive wave height.



Testing a protective layout consisting of wave screens at our physical test facility.

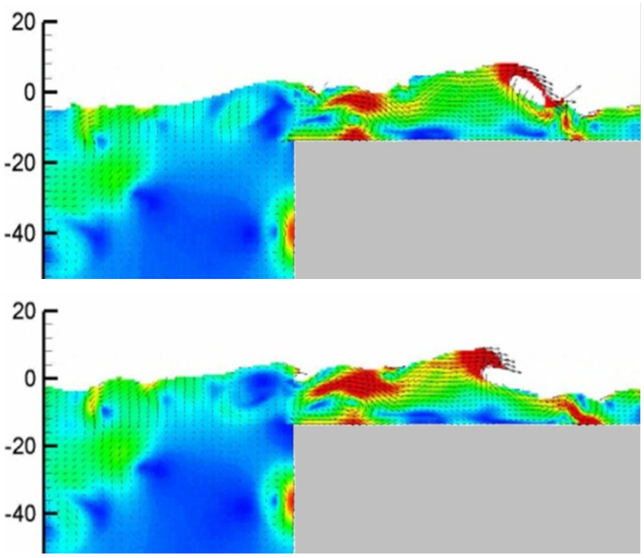
VERIFYING RESULTS WITH A PHYSICAL MODEL

A physical model was set up at a scale of 1:35 to verify the results established in the numerical models and to study the wave overtopping at the pier.

The comparisons showed almost identical results of the numerical and physical models, thus validating especially the wave breaking description in the 3-dimensional numerical modelling complex.

SELECTING THE OPTIMAL WAVE SCREEN DESIGN

The main objective of the physical model tests was to optimise the layout of the protective wave screens in front of the main buildings on the pier. A wave generator reproduced the waves and allowed to study overtopping and flooding for a number of alternative designs of wave screens.



Snap shots of wave breaking from our CFD model, NS3.

PREPARED FOR PERFECT SERVICE - TODAY AND IN THE FUTURE

DHI proved that complex hydrodynamic challenges, which cannot be handled accurately with a single model, can be solved by combining the strengths of different models to reach accurate, safe and cost-effective solutions. As a result, Falmouth Cruise Terminal can be confident of withstanding the worst of Jamaica's hurricanes without risk of flooding and will remain a welcome port of call for tourists to the island for years to come.

GLOSSARY

Wave refraction: the change in direction of a wave due to a change in its speed caused by e.g. varying water depths

Wave diffraction: the spread of wave energy into areas with lesser wave energy, e.g. behind a structure

Contact: Peter Sloth - prs@dhigroup.com
For more information visit: www.dhigroup.com