

PASSING VESSEL AND TIDAL FLOW IMPACTS ON SUBMERGED TUNNEL ELEMENTS DURING INSTALLATION

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INTRODUCTION

A number of numerical and physical model studies were used to assist in the design and future construction of the Oosterweel tunnel Project at Antwerp, Belgium.

An immersed tunnel, when completed, will connect left and right bank of the River Scheldt, see Figure 1. The tunnel will consist of 8 tunnel elements, to be immersed in water depths of up to 30m with ebb and flood tidal currents up to 2m/s. The design of the immersion and mooring systems are therefore a crucial part of the installation as well as understanding the effects of passing vessel on it, whilst in a temporary state before final back fill.



Figure 1 - Proposed location of the immersed tunnel at Oosterweel

The studies investigate the different hydraulic load cases on various tunnel elements (TEs) during and post immersion. The TEs will be placed starting from the Southern bank of the River Scheldt (Linkeroever) with elements suspended from catamaran pontoons during installation process, see Figure 2.

DESIGN CONSIDERATIONS

A number of considerations related to the installation of the TEs were investigated using CFD and physical models, these studied:

- Ebb and flood induced tidal flow loading on the TE during lowering and installation
- Ebb and flood induced tidal flow loading on the TE and in temporary state,
- Vessel induced loads for varying speeds, direction of travel and passing distances to TE.

Of particular interest was the behaviour of vessel induced forces. Passing ship effects are most usually of concern where berths are located along relatively confined waterways and/or close to navigation routes. In such locations, ships may pass relatively close to moored vessels whilst in transit to, or from their berths. In this particular study the interest was on the influence passing vessel will have on the TEs once installed on

the river bed, in a temporary state before being fully covered by backfill. Passage plans are to be put in place disturbing construction and it was import to validate the effects of vessel speeds and passing locations.

The prototype TE investigated was 158.8m in length, 41.3m wide, 9.9m tall and had a weight of 619,802 kN. The TE will be lowered from the pontoons using 4 hoisting wire connection points, whilst the TE is held in place using 6 anchor lines which are anchored to piles placed on the river bank or in the river.

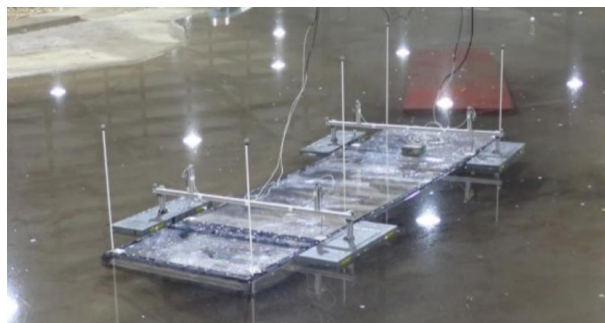
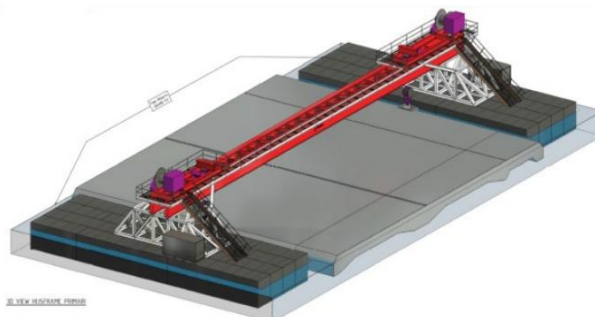


Figure 2 - Support pontoon design (top) and model TE, supported by pontoons under test (bottom)

During testing questions were raised on the influence of an installed TE's ability to cushion the motion of a suspended TE as its being place in position. Lining up and bringing TEs together is a critical part in the construction process and understanding the boundary effects of the gap between units was of interests to recognise its effect of strike risk.

CFD STUDIES

A series of CFD 3D simulation were completed by IMDC to investigate the flow behaviour around the TE at different stages of lowering through the water column. The tunnel element was formed as a fixed structure within the mesh and a steady state flow used to evaluate the hydrodynamic loads.

The simulations were completed using ANSYS FLUENT

and compared / calibrated against previous physical model studies (2008).

As well as performing flow loading simulations, the CFD tool was used to investigate the loading from a passing vessel, see Figure 3. The simulation was completed by moving a hull form along a fixed trajectory to induce a pressure field around the hull. The simulations were completed such that the vessel response to the bathymetry, river flows or vessel dynamics, such as squat were not included.

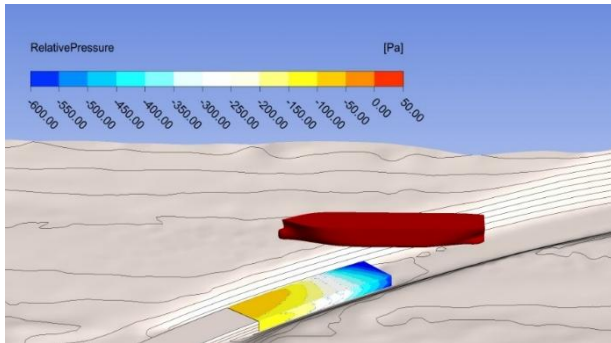


Figure 3 - CFD simulation of the loads induced by a passing vessel

PHYSICAL MODEL STUDIES

The physical model study was completed in HR Wallingford's wave and current facility using a Froude similitude scale of 1:56.5. The study reproduced the river bathymetry from bank to bank over a 1.7km stretch. This ensured that the current conditions were well represented by the time they encountered the test section and enough spacing was given to allow the model vessel, see Figure 4, to reach the constant target velocity.



Figure 4 - Passel vessel test

The physical model study was completed in a number of stages:

- Determination of model scale and design of the model layout;
- Construction of the bathymetry of the existing situation;
- Calibration of the flow conditions, with horizontal and vertical profile recorded and match to numerical model results;
- Following excavation of the tunnel trench, Tests investigate the loads on a near shore TE and mid-

stream TE during installation whilst being held in various positions and submerged depths with mooring lines, attached to piles, and hoisting lines;

- A further series of tests investigated current and passing vessel induced loads on TE, once on its temporary supports and after the gap beneath the TE had been backfilled with sand.

The following measurements were made to capture the required information from the physical model:

- Measurements of current flows were made using an Acoustic Doppler Velocimeter (ADV) during calibration and for a select number of conditions.
- In-situ mooring and hoisting line forces were measured using single-axis strain gauges installed at the end of each line.
- Six degree motions of the TE and pontoons supporting it during installation.
- Three degree motions of passing vessel relative to the installed TE.
- Six degree forces on the TE during passing vessel tests.
- Water level measurements to capture vessel induced waves and water surface elevations changes.

As previously mentioned the potential effect of water cushioning between an installed and swinging TE was investigated. Test were completed by changing 3 variables; TE to TE overlap area, gap between TE units and a surge (pull back) distance on a suspended (moored) TE. The mooring loads and TE motions were recorded, see time history in Figure 5.

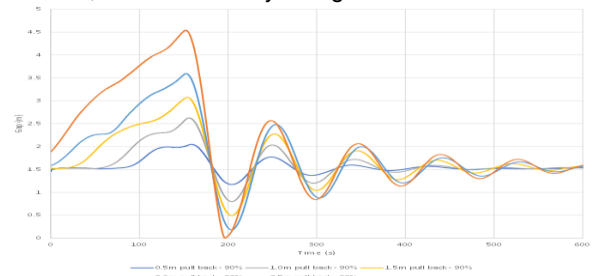


Figure 5 - Surge time series for varying pull back distances.

SUMMARY

The paper will present the use of CFD and physical modelling as complementary tools for understanding the complex processes associated with the installation of a tunnel element through tidal flows, particularly near boundaries, such as the water surface, river bed and dredged banks which can result in complex flow patterns and induced motions. The paper will present comparative findings between the results of the two approaches and highlight important parameters which need to be considered when using these approaches. The paper will also present findings on the effects of cushioning / damping between TE units.

REFERENCES

HR Wallingford, (2008). "Oosterweel Tunnel: Immersion and Ship Passing Tests", Report EX 5744.