TRANSLATION WAVES INDUCED BY HIGH HEAD LOCK SYSTEMS

JULIANA CANAL CASE STUDY

by

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ABSTRACT

The rate of transport to the hinterland over inland waterways is increasing in Europe. The vessels transporting the cargo continue to become larger. To provide the network that meets the markets demand, the dimensions of the waterways, canals and other hydraulic infrastructure, are being enlarged. To improve the European Waterways, the European Commission has granted the TenT-subsidy (Balazs, 2015 [1]). This research focusses on hydraulic infrastructure, in particular on the lock complexes. The lock complexes can be divided in low head lock systems and high head lock systems, this research covers the high head lock systems. Filling and emptying of lock systems create translation waves. In 1935, prof. Thijsse derived a theory on the propagation of translation waves in canal systems (Thijsse, 1935 [2]). This theory is used as the foundation to investigated the main goal of this research, to predict how translation waves evolve in a canal and what the consequences for the workability of water-borne construction equipment are. Accompanying processes for the construction works, such as construction inspections by divers, are included.

In this research the measures to reduce effects of translation waves are control options related to the lock complex only. Adaptations to the water-borne construction equipment or to the bathymetry of the canal are excluded from this research. Currents induced by other external factors than translation waves induced by the lock complex, are not investigated. The research is applied to a case study, the Juliana Canal.

The Juliana Canal is part of the North Sea - Mediterranean corridor and is a canal under reconstruction to meet the European regulations. In present state the Juliana Canal meets the demands of a "CEMT Va" canal and is now upgraded to comply with the regulations of the larger "CEMT Vb" vessels. Therefore it has to be widened and deepened. The construction works were granted by "Rijkswaterstaat" to "de Vries & van de Wiel", part of DEME-group. Arcadis is one of the sub-contractors, in the role of design support. These activities started in 2013 and are expected to be completed in 2018. The construction works are performed from the banks of the canal and with water-borne construction equipment.

The propagation and effects of translation waves in the intensively used Juliana Canal are investigated. The canal has to be attainable for shipping during construction works. The area of interest in this research is limited to the upstream section of Born, up to the bend upstream of the port of Stein in the Juliana Canal. The Middle lock chamber of the lock complex near the village of Born has already been enlarged to class "CEMT Vb". Larger lock chambers give larger translation waves, but no construction works to reduce the effects of the larger waves have been done so far to the canal itself. The combination of high shipping intensity and already large translation waves as a result of overdue construction works, create highly undesirable working conditions which reduce the workability for the water-borne construction equipment.

First step to achieve the main research goal is the development of a model to analyse how a translation wave propagates through a canal. Then the limit states of the water-borne construction equipment are determined. After that, the adaptation possibilities of a high head lock system are investigated and expressed in different scenarios. Finally, the scenarios are implemented in the model. The currents and water level changes under different conditions are analysed and advise is given on the different scenarios.

To predict the adaptations of water level changes and currents due to translation waves a 1D-model is developed. In the model, theory from Thijsse (Thijsse, 1935 [2]) on the development of a translation wave is applied and extended on more complex discharge extractions from the canal. Where the theory is limited to the changes of a single pulse, the total discharge-time relation of filling the lock chamber is implemented in the model. The discharge relation is divided in subsequent pulses of one second. The propagating and reflecting of each pulse through the canal is calculated, subsequently the pulses are placed after each other resulting in the total translation wave. The bathymetry of the canal-system determines the transition points and reflections, a schematization of the modelled canal section is given in figure 1. The modelled locations are presented in the figure as well. To obtain a good representation of the translation wave in this canal, a set of 42 reflections were included in this model.

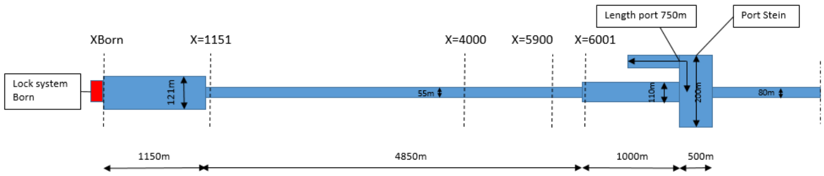

Figure 1: Scheme of the bathymetry in modelled canal section.

If the currents in the canal become too large, unworkable construction situations arise. The current at which construction works or accompanying processes can no longer continue, is defined as the limit state. The decisive process that determines the maximum allowable current by translation waves in this case study, is the inspection by divers. The maximum current towards the north is determined at $u_{min} = -0.13 m/s$, to the south at $u_{max} = +0.30 m/s$. Other limit states or limit states for future projects can easily be implemented in the model. The measures taken to reduce the impact of translation waves in the canal are limited to adaptations in control of the lock complex. Two control options can be done at the locks. The first option is regulating the magnitude of the discharge to fill the lock chamber. This is normally done by defining the number of culverts used during filling. The second option is to vary the time between sequent fillings. The scenarios modelled first, are filling with 1 culvert, 2 culverts which is the present situation, 4 culverts which is a theoretical case and filling two chambers simultaneously. The scenarios for the second option are filling the East lock chamber 5, 10 and 15 minutes after the Middle chamber. This is performed for fillings with 2 culverts and with 1 culvert.

In the present situation, the currents exceed the defined limit state due to translation waves. None of the investigated scenarios result in no downtime but the downtime can be reduced significantly. The most favourable scenario from the first group of control options, vary between 1, 2 and 4 culverts, depending on the location. Simultaneous filling is at none of the locations the best scenario and should be avoided. In the second group of control options, the scenario where the lock chamber is filled with one culvert and 15 minutes between sequent waves, results at 4 of the 5 locations in the least downtime. At the other location the best option is the scenario where the chamber is filled with 2 culverts and also 15 minutes between the waves. There is not a scenario that is the best scenario for all locations along the canal. The resulting water level change and current are the summation of the original wave and reflection waves. The reflection waves are created by e.g. reflections at a port or changes in the width of the canal. The distance of the construction location to these transition points determine which reflections, and with what magnitude, are at that specific location. This makes the net water level change and net current very location dependent. For each location the model has to be run with different scenarios. This can be seen in figure 2, where the resulting currents of the same 3 scenarios with 2 subsequent waves are modelled. The effects of different time periods between subsequent waves have contrary results for the maximum currents of the second wave.

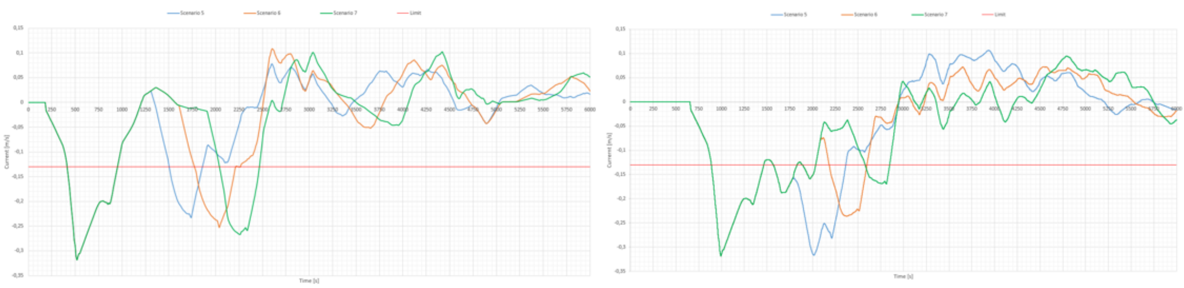

Figure 2: Results of 3 scenarios modelled at X1151 and X4000

Concluding, the model gives a good representation of the situation in reality, for the modelled locations in canal. For future projects, the model can relatively easy be adapted to another canal-system by changing the bathymetry, lock discharges and transition points. The model is applicable to gain insights of a system for designs. It can be used as a decision tool during construction works as well due to the short calculation period. The use of this model can forecast the working conditions and limit the downtime.