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Evaluating lock gates' strength due to ship collisions: A Douro waterway lock gates case study

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ABSTRACT

This paper presents a crashworthiness case study where is evaluated the Douro river lock gates' strength due to ship collisions. The increasing traffic in the Douro waterway and the prospect of reopening the Moncorvo iron mines have settled the conditions for starting the preliminary works on the modernisation of the waterway. Since the construction of the Douro river lock gates, the mass of the ships navigating the waterway have increased from a maximum of 2200 tons–2900 tons, so the evaluation of the lock gates' crashworthiness to ship impacts needs to be updated to the current navigation conditions. A methodology to solve the impact problem is firstly defined in terms of simulation type, geometry definition, impact location, material model and contact model, taking into account the procedures in [9]. This methodology is then applied to the Carrapatelo upstream lock gate and using the Abaqus/Explicit solver, finite element dynamics simulations were performed to evaluate the response of the lock gate to impacts by two different ships at variable water levels. The greatest risk associated with the impacts is pondered to be the possibility of the gate falling into the lock chamber, or that its deformation is enough for a large mass of water to fall into the lock chamber. In order to evaluate this, a series of criteria that quantify the damage delivered to the lock gate and its supports are defined. The obtained results show that the damage in the lock gate is not sufficient for the occurrence of a hazard with possible loss of life. However, for one of the impact cases, the reaction force on the chains that connect the gate to the electromechanical actuators was equivalent to 3.6 times the expected load from the static weight of the gate, which is believed to be dangerous for the operation of the lock. Finally, the possibility of using an energy dissipating mechanism to reduce the damage in the lock gate is evaluated, and the results show good improvement on that course.

1. Introduction

The lock is an important infrastructure for inland water navigation. Due to high flow rates, without human intervention, inland waterways (rivers, lakes, canals, et cetera) are at best seasonally navigable for commercial purposes. By constructing dams the flow rate can be controlled, leading to safer navigation. This creates yet another problem which is that ships need to navigate through the water head created by the dam. In order to permit this, a chamber with changeable water depth, occupying a small portion of the dam, raises and lowers the ship inside it (see Fig. 1). This procedure places the ship at the same water level as the portion of the river it needs to travel to, allowing its safe passage.

In a simplistic form, a lock is composed off a chamber (where the water level can be varied), an upstream and a downstream gate, and two valves. In advance to a vessel approaching a lock, the water level in the chamber should be equalised to the water level

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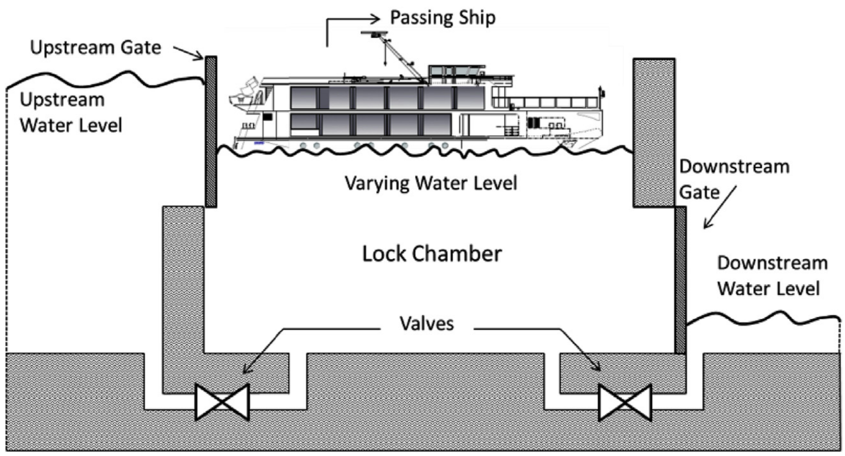

Fig. 1. Longitudinal cut of simplistic navigation lock system with a ship traveling downstream.

where the vessel is. For a vessel traveling downstream, the upstream gate is then opened and once the vessel is inside the chamber, it is closed. By actuating the downstream valve, the water in the chamber flows through gravity to the downstream part of the waterway, up to the point that the water level in the chamber is the same as downstream. The downstream gate may then be opened so that the vessel may proceed.

There are three main types of lock gates used in commercial navigation: the sliding gates, the vertical gates and the mitre gates (which are the preferred option in most of the waterways). These gates are quite well described by Ref. [7]; for this work there is a particular interest in the vertical gates as the lock gates in the Carrapatelo lock are of this type. The upstream gate is of the vertical drop type (Fig. 2), so the gate is lowered when being opened, allowing the ship to pass above it. While the downstream one is of the vertical lift type (Fig. 3) and so the gate is lifted when it is being opened, allowing the ship to pass bellow it.

We have witnessed in recent years a steady increase in tourism related traffic in the Douro waterway and a renewed interest in reactivating the Moncorvo mines. This has created the necessary conditions so that the first steps for the modernisation of the Douro waterway may be taken. As part of this modernisation project, impact safety in the lock gates present along the waterway is being reviewed, since previous studies regarding impact safety on the Douro lock gates date from 1970s. In these studies the maximum mass of the considered ships was 2200 tons [17], but current directions impose that the vessels navigating in the Douro waterway should not exceed a mass of 2500 tons [2], limit which is expected to be risen to 2900 tons in the near future. This escalation on the mass of the ships navigating the Douro river urges that new studies should be conducted with the purpose of certificating the lock gates for the new impact conditions. Besides that, current computational methods can be useful in performing more detailed studies than the ones conducted in the 1970s.

The aim of this work is therefore to evaluate the performance of the existing lock gates on the Douro river when impacted by recreational ships that currently navigate the river and by the ships expected to transport the ore from the Moncorvo mines. In order to achieve this, a methodology to assess the crashworthiness of the lock gates is selected, which is then employed using the *Abaqus/*

Fig. 2. Upstream lock gate in closed position.