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1- The Third Set of Locks Project

The Panama Canal Authority (ACP) decided to build a new lane along the Panama Canal that will double capacity and allow more traffic (Figure 1). Along with this new lane, two sets of larger locks, referred to as the Third Set, is under construction as from 2009, one set of locks in the Pacific end and another one in the Atlantic side. Each set of locks will have three consecutive chambers with lengths varying between 427m and 488m, depending on the position of the inner gates, and a width of 55m. The design ship is a so-called New Panamax 13 000 TEU container carrier (366 mx48.8 mx15.2 m; CB=65%). Because water consumption is a major issue, each of the 6 new Locks will be equipped with 3 Water Saving Basins (WSB).

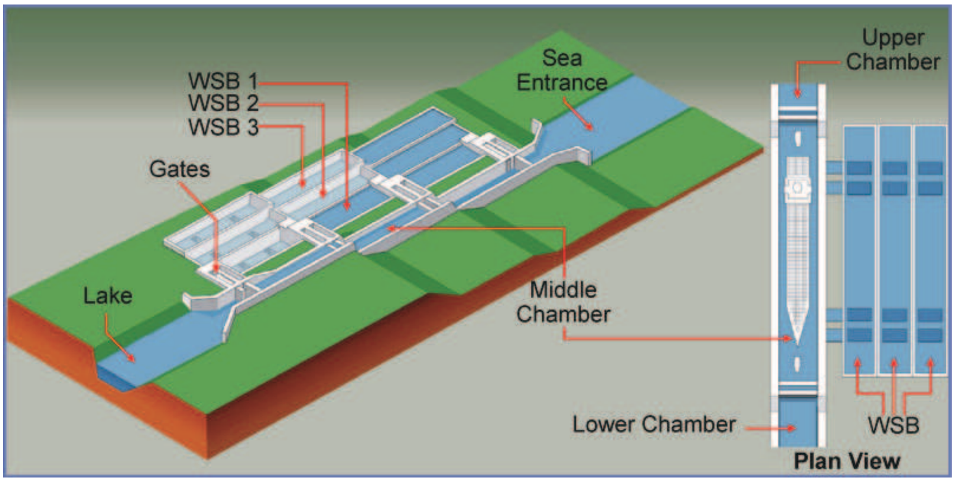

Figure 1: Third Set of Locks structure – Overall view

This “3 locks & 9 WSB” configuration will help to save 87% of the water required for the transit of one ship between from Pacific ocean to the Gatun lake and the Atlantic ocean (as compared to a single lift lock with no WSB). Even though the New Locks will be wider and longer than the existing locks, they will consume 7% less water than the latter when the WSB are used.

2- Hydraulic design of the New Locks

The final design of the locks F-E system has been carried out using both a physical scale model and a set of 1D, 2D and 3D numerical models. The validation of F-E system final design had to be carried out in 16 months since this step was on the critical path with respect to the locks construction schedule.

The physical model (Figure 2) has been run in the Laboratory of the CNR in Lyon while the numerical model studies were performed by MWH in Buenos Aires. Initially, numerical models had been run to fix the design to be tested in the physical model. Then, each model was run at the same time, allowing to cross-check the results and to minimize the time to achieve the validation of the hydraulic performance of the F-E system.

The scale model, 60 m long and 10 m wide, representing two lock chambers, three Water Saving Basins (WSB) associated to the lower chamber, one fore bay and one tail bay has been built at scale 1/30 in CNR laboratory.

Figure 2: General view of the physical model

This model has been equipped with about 100 sensors in order to measure the water levels, the longitudinal and transversal water slopes, the velocities and flow rate in the main culverts and WSB conduits, the pressure in the culverts and downstream the valves, the valve positions and the longitudinal and transversal hawser forces (i.e. the longitudinal and transversal components of the hydrodynamic force exerted by the water on the ship's hull).

A set of three ship models (one 12 000 TEU Post-Panamax containership, one 8 000 TEU containership and one dry bulker) at scale 1: 30 were used for carrying out the tests in the physical model.

The tests have been carried out through 4 tasks, starting with tests in steady flow conditions used to assess the flow distribution along the lock chamber and assess the head losses in the F-E system. The two following tasks aimed at verifying the F/E system proposed in the tender design by the Contractor will permit to comply with the hydraulic performances requested by the ACP. The last task aimed at assessing the F/E system performance for debased conditions (i.e. for different equipment availability scenarios) but also for specific type of vessel other than the design vessel.

At the end of the study, more than 1 500 tests were performed on the physical model.

Concerning the numerical model studies, state-of-the-practice software was used to study the different problems:

- Local head losses at the different system components were computed using 3D models based on OpenFOAM;
- The filling/emptying times and maximum flow velocities were calculated with a 1D model based on the commercial software FlowMaster V7;
- The hawser forces were inferred from the water surface slope values correlated during previous design phases. The water surface slopes were obtained using a 2D model based on Hidrobid software (a numerical code developed by Instituto Nacional del Agua) which is similar to other software like Mike 21, or Delft2D.

All the models went through calibration or validation processes. The validation of OpenFOAM was based on comparisons with existing experimental results. The 1D model was first calibrated by comparison with experimental results from measurement carried out on the conceptual design physical model and with the results of the 3D models. Then, when the physical model tests started, the results achieved were also used. The 2D model was validated by comparing its results with the results obtained with software Delft2D, and with measurements performed in the physical model.

The combined used of physical and numerical model gives birth to a very powerful “hybrid” model that helped minimizing the calculation time, cross-checking the results, accessing to a large number of data and improving the prediction of the hydraulic performance of the prototype.
The following examples can be quoted to illustrate the complementarities of each model:

- The calibration of the 1D model of the F-E system according to the measurements preformed on the physical model (discharge, pressure drop). The 1D model has then become a very efficient tool allowing to perform fast sensitivity analysis, in order to define the valve opening schedules before testing them on the physical model. The construction of two 1D numerical models, one at scale 1/30 and the other at prototype dimensions, has also given very valuable information on the scale effects.

- The assistance brought by the 3D numerical model for carrying out measurements on the physical model to assess the flow distribution through the lateral ports. These measurements were carried out with propellers positioned at the mouth of the port in the lock chamber. Anyway, the flow existing each of the 20 ports along one lock wall is not symmetrical with respect to the vertical and horizontal axis of the port because of the velocity component in the secondary culvert as shown on the Figure 3:

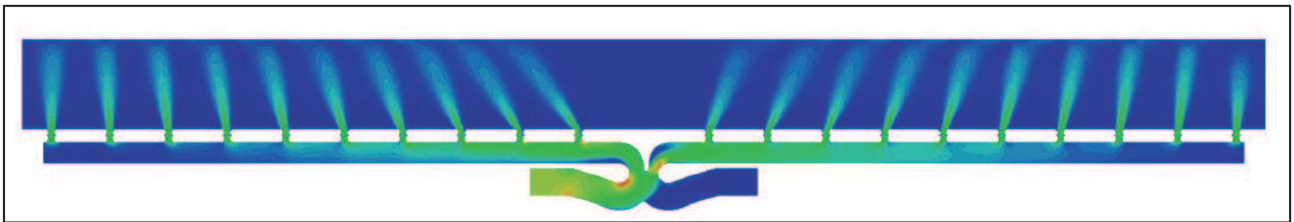

Figure 3: Flow direction in the ports

Measuring the discharge through the ports the closest to the central flow connection required consequently a particular attention and it could not be performed with one single measurement with the propeller positioned in the port axis. Calculation realized with 3D numerical model gave very valuable data, such as distribution of the flow in every port and allowed to set an appropriate measurement protocol for every port All this set of data allowed to get an accurate and comprehensive knowledge of the flow conditions in every port and to validate the efficiency of F-E system regarding the flow distribution.

- The upgrading of some components of the F-E system Tender design and especially one of the main culvert valve layouts. The series of tests carried out on the physical model allowed to detect visually that some air was sucked in the main culvert downstream of the valve n°5 (as shown on Figure 4) but not downstream to the valve n°6 while both of them were opened according to the same schedule.

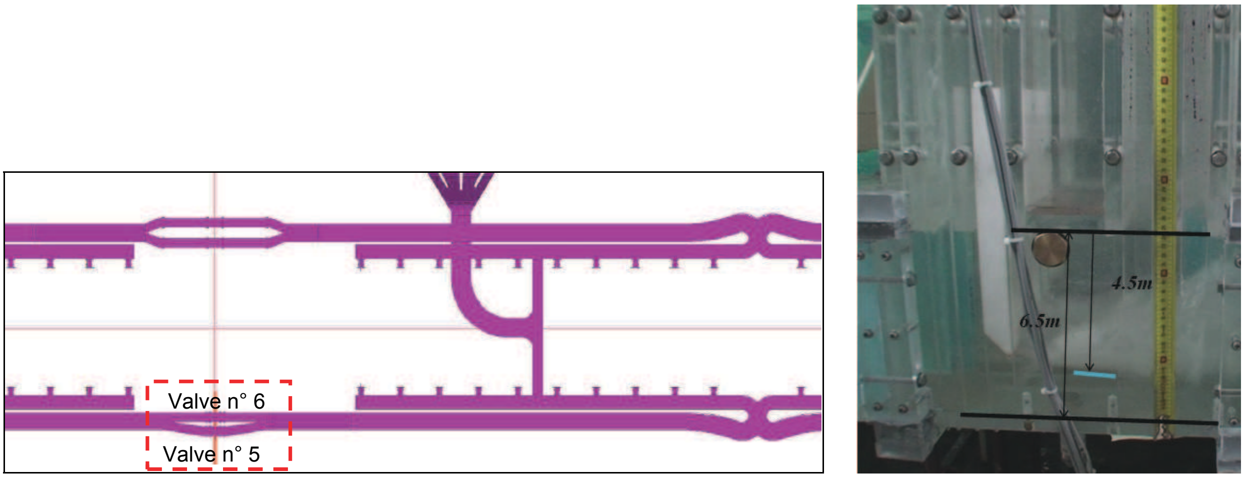

Figure 4: Air entrainment under valve n°5

A 3D numerical model of the valve has been implemented. It was validated on the basis of data measured on the physical model (especially pressure) and helped selecting rapidly the most adapted layout to solve the problem. The retained configuration has been installed on the physical model for validation. It finally proved to work perfectly as expected according to the numerical model results. This methodology has permitted in a very short time (i.e. less than 3 months) to ensure the results by cross-checking the data on both model and to optimize the F-E system modification from a financial point of view.

The simultaneous implementation of several numerical models a scale physical model allows to define the Final Hydraulic Design of the Panama Canal Expansion Project in the expected time schedule, each one providing different advantages and allowing to overcome the characteristic limitation of the other.

3- Construction status and progress

As of April 2012 the design and construction works have a 22% overall progress. The final designs are 59% advance particularly for the upper and middle chamber of Atlantic and Pacific locks. Excavation of 26 million m^3 of rock and dirt has been done so far which is half of the estimated total amount. The equipment, plant deployment for crushing rock for aggregate and concrete mixing plants are completed. About 600,000 m^3 of concrete has been placed which is close to 14% of total estimated quantities. Reinforced steel is arriving and is being installed and climbing forms are used. The once small model main culverts 8.30 m wide x 6.50 m tall are being formed, its size and area 54 m^2 are impressive to the visitor (see Figure 5). Wagon type valves 4.15 m wide x 6.50 m tall are being fabricated in Korea and the huge rolling gates up to 3,500 tons each are being fabricated in Italy. The Contractor is increasing resources and expects to finish the work on time. The works are advancing and what started has numerical model and small physical model is now becoming a reality and the new third set of locks of the Panama Canal will soon expand the country's service to the maritime world commerce!

Figure 5: Construction progress of Third Set of Locks upper chamber