Conceptual Design of Post Panamax Locks
Triple Lift Lock System

Diseño Conceptual de las Esclusas Pospanamax
Sistema de Esclusas de Tres Niveles

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Resumen Ejecutivo

Executive Summary

Task 4 – Conceptual design – Configuration 1 : triple lift lock system.

This report contains the conceptual design of a triple lift lock structure for the new Post Panamax locks at the Pacific side of the Panama Canal.

The design criteria for the detailed design and the construction works are given in the report of task 2; while the alignment of the new by-pass canal on the West of Miraflores and Pedro Miguel locks is analyzed in the report of task 3 "Alignment Optimization".

Task 4 contains following subtasks:

- a. Lock siting and Lay-out
- b Lock Walls
- c Emptying and Filling System
- d Lock Operating Gates
- e. Culvert and conduit Valves
- i. Entrance Walls

Other tasks, such as electro-mechanics, construction planning and cost estimation are described in Part B of the Task 4 Report.

For each of these tasks a separate report has been prepared, together they make the report (Part A) of this task 4.

Before resuming the results of these conceptual studies, it is important to remind that the design is especially based on following special criteria and requirements, as has been discussed on several occasions with ACP:

- The new locks are a capacity driven system, and therefore the performance is of utmost importance
- Reliability is another basic requirement, as any shutdown time means loss of income
- Maintenance has to be kept to a minimum
- Construction cost should be minimized
- Operation facilities and systems should be kept simple and reliable

Lock siting and layout

As the alignment has been analyzed and chosen (see task 3 – Alignment Optimization), the lock siting and layout have been further examined taking into account following boundary conditions and requirements:

General:

- *Geological conditions*:
  The lock structure has been shifted in the longitudinal direction until the lock heads are situated each of them in a homogeneous subsoil, either "La Boca" or "Basalt" formation.
- *Minimize excavation*
  It is obvious that a position at the south side of the by-pass canal is the most favorable one.
- *Nautical access*
  The entrance of the locks at the Pacific side has to be at a distance of 5 x the ship length away from the existing canal area.

Specific:

Some specific criteria had to be taken into account for the final layout; according to the T.O.R.

- *Vessel position system*:
  The conceptual design has been done taking into account that the vessels will be moved and guided through the locks by means of a similar system as on the existing locks.
  This locomotive system requires the following provisions:
  - a double rail track system at both sides of the lock (towing and return track), with a total width of 15 m
  - long entrance walls with a specific lay out at both entrances of the lock

- *Fourth lane provisions*:
  According to the T.O.R., provisions have to be made for a fourth lane construction. In this future situation, a canal width of 6B (+/- 330 m) will be required in order to allow two-way traffic. In order to minimize excavation it is envisaged that the distance between the third and fourth lane should be determined in order to fit into the 6B canal width, while the first phase canal profile (4B width) should normally be within the center of the third lane.

- *Water saving basins*:
  The T.O.R. demand that the locks shall be provided with water saving basins (WSB). As these basins take a lot of space along the lock structure, they play an important role when determining the lock lay out.

The final lay out, as a result of this concept design study, is shown on drawings D3-A-001 & 003.

Lock walls

The choice of the lock wall type depends mainly on geo-technical and seismic conditions, loadings (water levels, sill levels) and filling and emptying system.
As the lock structure is situated mainly in rock bottoms, a number of possibilities of lock wall type is excluded.
As loading conditions are rather severe, and the requirement to have a very performing E/F system (with large culvert dimensions), the choice of a gravity type lock wall has not been difficult to make.
Of course it is clear that even the gravity type lock wall may lead to a lot of different alternatives which have to be investigated and optimized during further studies.

In this conceptual design, the lock wall dimensions have been chosen primarily in order to minimize excavation, further an option with reinforced concrete structure has been evaluated against an option where roller compacted concrete (RCC) has been applied.
Typical sections are shown on drawing D4-B-006.

Two different cross-sections of locks walls are required in order to cope with deformation criteria in two different subsoil conditions (La Boca and Basalt).

Finally, as the lock walls are situated mainly in rock, it is suggested that no structural lock bottom floor will be required. Only in the "La Boca" area, a concrete layer has to be installed to avoid weakening and erosion of the soft rock.

Special attention has been paid to the load cases:
- earthquake
- dry lock chamber condition

It is shown that the dry lock chamber condition is more stringent than the earthquake event. The dry lock chamber has been considered as an accidental loading condition.

Filling and emptying system – Water Saving Basins

The T.O.R. require that two types of emptying and filling (E/F) systems have to be worked out, and that the design shall be done taking into account the use of water saving basins (WSB). We refer to the T.O.R. p. 10/21 "For concept design, the systems shall incorporate the use of water saving basins and be presented to ACP for selection of the desired arrangement".

CPP has developed two different systems of E/F, one of them will be the most economical system if water saving basins are used, the second one will be somewhat more expensive in construction cost, but will function as good with or without water saving basins. Both systems are described and documented in R4-C.

As ACP has clearly confirmed that the second system will be preferred, this system has been retained for structural engineering purposes.

This system is explained on drawing R4-C-001 and can be described as following:

- continuous culverts at both sides of the locks are integrated in the lock wall structure (dimensions 7.5m x 9m),. they allow operation of the locks without WSB.
- both longitudinal culverts are linked with the lock chamber through the side walls by means of ports (2m x 2m), equally divided over the chamber length central part, in order to guarantee an equal filling and emptying.
- Water saving basins (3 parallel basins for each lock chamber situated at the east) are linked to the culverts by two conduits per WSB for each culvert (total of 12 conduits per chamber with a section of 5.5m x 7.5m)

Attention has to be drawn to the fact that the system has been selected as being integrated in the lock walls, which is much more cost-efficient and maintenance free than a system with openings in the lock bottom floor (such as in the existing locks). The ports in the side walls can be closed by means of bulk head slots, and this way it is no longer necessary to retain the dry lock chamber condition. This allows a more economic design of several lock structure elements (lock gates and lock walls).

Lock Gates.

Lock gate selection and analysis for the triple lift lock configuration has led to the application of the "Rolling gate" type. This choice has been justified by means of a multi criteria analysis to evaluate the miter gates and the rolling gates. The rolling gate type is the only existing lock gate type for this size of Post Panamax locks, and has been successfully used in Europe, especially in Belgium where the locks of Berendrecht, Zandvliet in Antwerp and Vandamme in Zeebruges are the largest in the world.
Furthermore, the rolling gate type has some particular advantages which are of utmost importance for the new locks which will be capacity driven. One main advantage is certainly that the gate is moved horizontally in the transversal direction of the lock, into a lock gate recess chamber, which can be easily dewatered, and as such represents an ideal maintenance place and position. As there are two lock gates and lock gate chambers on each lock head, it is practically impossible that the traffic should be interrupted due to failure of a lock gate. Moreover, a lock gate can be floated and can be towed away as a vessel if necessary (for example replacement, or using the gate as a bulkhead to dewater the lock chambers).
The rolling gates have been designed for the normal operating conditions, as the dry lock chamber condition will not be retained as a basic requirement. Although, the outer gates have been designed to

withstand the total water head which occurs during the dry lock chamber situation. The procedure to empty the triple lift lock structure would be that the outer gates are floated away from their normal position to additional recess positions up- and downstream, where they can be positioned and sunk to retain the water head from Lake Gatun and the Pacific Ocean.
Other alternatives are possible, for example a configuration in which each lock gate head can be dewatered using the gates as bulkheads, this would only require additional recesses around the lock heads.
The lock gate structure has been analyzed using 2D-structural engineering software and according to the expert's experience with rolling gates in Belgium. This analysis allowed to determine and verify the general dimensions of the different gates, the dimensions of the steel truss structure, and consequently it was possible to make a fairly accurate estimation of the weight of the steel structure.
Other auxiliaries, such as wheel barrow wagons, supports, etc, have been assessed according to the experience with the Berendrecht and Van Cauwelaert locks in Antwerp, which were also designed by the CPP-experts.

Culvert and conduit valves.

Similar as for the lock gates selection, a multi criteria analyses has been done to select the most convenient valve type for the culverts and the conduits. The most suitable valve is the fixed wheel valve with vertical translation, moved by means of vertical hydraulic cylinders.
This is the same type of valve and system which is used at the Berendrecht lock, and has proved to be very reliable.
In order to guarantee a maximum of reliability, the valves on the culverts are made redundant (two parallel valves per culvert, each operating on half of the culvert secton. Each valve has a rectangular section of 7.5m high x 4.5m wide.
The valves on the conduits (in between the water saving basins and the lock chamber culverts) are not made redundant as such, but there are always two conduits for one WSB, which in fact gives the same redundancy as for the culverts. The valves on the culverts are 7.5m high x 5.5m wide.
Opening times of 2min (opening) and 1min (closing) have been considered and can be achieved.
The valves have been designed for maximum operating and maintenance conditions, can easily be set in dry conditions using bulkheads at both sides of the valves, and can be reached through vertical shafts on both sides.

Entrance walls.

Entrance walls have been designed according to the layout and the requirements of the imposed vessel positioning system with locomotives, which lead to a long western entrance wall.
The wall type which has been retained is similar to the lock wall, but doesn't require the integration of the culverts, and is not exposed to the same water heads.
Proper fendering will be installed at the lock entrance to avoid damage to the walls and lock gate recesses.