CONSTRUCTION OF A STABILISED TIDAL INLET IN COLOMBIA

Cleaning and Improving Cartagena's Water Quality

This article gives an insight into the topographical and hydrographic aspects of the construction of a stabilised tidal inlet in Cartagena, Colombia. The purpose of this tidal inlet was to improve the water quality of the highly contaminated CiÃ©naga de la Virgen lagoon at the outskirts of Cartagena by forcing a current of clean water through the shallow CiÃ©naga de la Virgen. Works for this project consisted of the construction of breakwaters, a box culvert, canal, sluices, separation wall, dredging and beach replenishment.

Project preparation began in 1998 by checking all available benchmarks as defined in the design drawings. A few appeared to be missing and the remaining ones were checked for their quality. A differential GPS station was set up at an assumed position, which was established by logging for 24 hours. The LRK receiver was programmed with the SADâ€™69 datum and positions logged at each benchmark were recorded during 20 minute periods. The coordinates for each point appeared to be very large (Â± 300m) but consistent with the other ones, which indicated an error in the transformation constants. I therefore decided to determine the transformation constants myself by logging on the benchmarks again and calculating the coordinates in ECEF coordinates.
The inverted coordinates were then applied as transformation constants in the LRK receiver and checked on one benchmark which was assumed to have a correct position and to be level. This time the coordinates appeared to be within the system accuracy. Later it was learned that the grid in Cartagena was a local grid established astronomically in the 1950s, which may explain the differences found.
Because of the considerable extent of the project (4km from one end to the other) and the required accuracy, a local grid was established. This grid was an exact copy of the Gauss Colombia grid with the scale factor being 1,000,000 at the construction site. Within this grid, a third grid in chainage and offset was defined with the chainage axis running over the channel centreline.
After this, a network of benchmarks was set out at the construction site. The benchmarks consisted of metal tubes with a stainless steel fitting for a total station. The initial position for the benchmarks was obtained by logging with LRK for 20 minutes and taking the mean of the logged data. Furthermore, distances and bearings were measured with a total station. Positions, distances and bearings were adjusted using MOVE3.1. During the project this network was adapted several times. In addition, the location of electricity, water, gas mains and telephone and video cables had to be established to prevent damage and to prepare for relocation.

Bocana Breakwaters
To protect the entrance of the canal, breakwaters had to be constructed. First a detailed hydrographic and topographic survey of the area was made. With these data the final design was established and construction started. The dry part of the breakwater was measured in the normal way with a total station and LRK. The underwater part used a crane with an extended boom. A special measurement tube was fitted to the boom. The measurement tube consisted of a 6-metre pipe with a prism ring on one side and a hemisphere on the other. The radius of the hemisphere depended on the size of stone to be measured. The height of the prism ring could than be measured by total-station. The area between the breakwaters was to be used as a sediment trap for the channel and therefore it had to be dredged after completion of the channel.

Bocana Canal
Construction of the channel consisted of wet and dry excavation. The first layer was excavated from ground level to 1 metre below groundwater level, then the water was pumped out and deep wells were installed to keep the channel dry during construction. The ground water level in the channel had to be maintained at under -6.00m during excavation work. When the channel had dried out sufficiently the second layer was excavated and rock protection was applied to the bottom and slopes. The Movicon surveyors carried out interim and surveys with total station and levelling at regular intervals. Meanwhile a bund was constructed in the CiÃ©naga de la Virgen from the excavated material for excavation of the outflow area and the construction of the separation wall. After excavation of the outflow area, rock protection was applied.

Bocana Sluices
To regulate the flow of clean and dirty water in and out of the CiÃ©naga a complex of sluices was built. This consists of six inlet and four outlet sluices. Each sluice has two doors, which are opened and closed by water-pressure and operate without any human or mechanical involvement. The doors open with a very small difference in water level at each side. The difference between high and low-water is 0.30m at a spring tide and 0.15m at a neap.
Construction of the sluices contained various critical items like door pivots, hinges and galvanised profiles that had to be aligned to within 0.5cm. First, the galvanised profiles were installed using wooden moulds. These profiles transfer the horizontal forces exerted on the bottom of the door into the concrete. After pouring the concrete around the profiles, the concrete for the separation walls was poured leaving open a small section where the top hinge could be connected with the reinforcement bars. First the pivot was placed correctly

using a tape measure and a level, and welded to the base. All measurements were taken with the galvanised profile as a reference. With the pivots in place the hinges were fitted with a specially made tube. This tube was set-up vertically on the pivot as a support for the hinges which could connected to the reinforcement bars. All alignment was done using lead lines and tape measures; this proved to be more accurate than by total station. To damp a swinging lead line a bucket of water was used.
After pouring the last concrete the sluice doors could be installed. Each door has one beam running horizontally at the bottom and two posts running vertically at the back and the inside of the door. The objective of adjusting them is not to make a watertight door but to transfer the forces caused by the water pressure into the concrete. Adjusting the back posts has to be correct the first time because they are not accessible with the doors in place. With the doors in place the distance between the back of each door and the concrete was measured at regular intervals and the back post was adjusted accordingly, fitted on the door and checked. Now the inside post and the beam were fitted and adjusted. With the doors in place and beams and posts adjusted the sluices were ready to be used.

Separation Wall
To force the clean water in the CiÃ©naga and the dirty water out a 3km-long separation wall was made of sheet-piling, beams and support pipes. The separation wall consists of three sections and topographic points were made at each corner on top of a support pipe to create a total station platform. The water of the CiÃ©naga was used as a reference on a quiet morning to transfer levels from the land to the various topographic points. To do so the water level in the CiÃ©naga was taken and at a topographic point. There a plastic tube with a small hole drilled in it was pushed into the mud and a levelling rod was placed inside it to allow an undisturbed reading of the water level against the top of the total station platform.

CaÃ±o Juan Angola
The CaÃ±o Juan Angola is the other connection of the CiÃ©naga with the sea. This canal had to be cleaned and dredged by crane and at the CiÃ©naga end an extension and a new mouth had to be constructed. Furthermore, the canal was heavily polluted by two sewers, which had to be relocated to prevent direct inflow of polluted water into the CaÃ±o. This canal was too small and too shallow to be sounded conventionally. Surveyors of Consorcio del Caribe carried out the survey with basic equipment like a level, a levelling rod and a measuring tape. As a reference the base of the fence of the airport, running along the Caâ€"o for the whole length, was used.

ChambacÃº
To prevent the inflow of dirty water from the Bay of Cartagena into the CaÃ±o a second sluice was constructed at ChambacÃº in the centre of Cartagena. This sluice had one pair of doors. The main problem was the difference in level between datum and the local geoid. Therefore the sea-water levels were measured with LRK between the breakwaters near the box culvert and at the ChambacÃº site. A difference of 0.10m was found over a 5km baseline. Later the same was repeated for the box culvert Boca Chica baseline with a length of 15km giving a difference of 0.30m. Both baselines were running in the same direction. Construction of the sluice was carried out in the same way as the Bocana sluices.

Crespo
In the final stage of the project beach replenishment and construction of four breakwaters had to be carried out at the Crespo neighbourhood. The sand for the beach replenishment was dredged between the Bocana breakwaters. As a limited amount of money was available to construct the breakwaters a spreadsheet was made for a 'what-if' analysis. Various parameters as unit prices, stone type, layer thickness, length and water depth could be filled in giving a direct insight into construction costs. Using this spreadsheet a final design was presented to the project supervision for approval. After approval construction could be carried out in the same way as the Bocana breakwaters

Monitoring
During the project morphological and chemical surveys were carried out at monthly intervals. The morphological surveys consisted of 2km long lines perpendicular to the coast on both sides of the Bocana breakwaters. These surveys were carried out to establish the effect of the construction of the breakwaters on the beach.