Application of geosynthetics solutions in the construction of 'El Salitre' artificial beach - Chile

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1. INTRODUCTION

This document briefly describes the main technical aspects related with the design and installation of the coastal protection structures and other geosynthetics engineering solutions applied in the construction of new 'El Salitre' artificial beach, located in the city of Tocopilla, Chile. The project aimed to rehabilitate an environmentally degraded coastal area by creating a new good quality and stable recreational beach. The project was implemented between 2017 to 2018 as part of a compensation initiative planned by the Chilean government for promoting the urban and tourism development in the northern region of the country after the large infrastructure impacts caused by a high magnitude earthquake occurred in 2007. The progressive contamination of 'El Salitre' area was historically produced in previous decades by the contiguous port and adjacent local thermoelectric plant activities, resulting in extremely inadequate concentration levels of coal and other minerals (such as copper and zinc) within this coastal environment (i.e. marine sediments and superficial beach sand). In addition, the degradation process was strongly intensified by the predominant direction of currents and wave local systems. Accordingly, the project not only included the environmental recuperation of the beach area, but also all complementary civil works in order to ensure effective long-term coastal protection against complex hydraulic erosion actions typical from this region of the Pacific Ocean. The erosion control works basically consisted in the construction of three associated coastal structures (breakwaters) specifically designed to mitigate the impact of waves as well as tidal changes and marine currents over the bathing area, enabling moderated and controlled hydraulic exposure and fulfilling a number of key technical requirements (stability, safety and clear and clean water). Based on a rigorous study of a wide range of construction methods, materials and design alternatives, geotextile system solutions were selected (i.e. geotextile tubes and geotextile scour aprons) for the conformation of the two main breakwaters cores, which allowed not only the permanent confinement and use (as filling material) of a part of the contaminated sand from the original beach, but prevented its treatment or final disposal in open sea. Similarly, two layers of high strength woven and non-woven geotextiles were designed as a separation and filtration element between the remained contaminated material and the new imported clean sand layers. Some of the main challenges and most important aspects of the design and construction stage will be generally presented.

Figure 1. Project implementation area and origin of contamination.

2. DESCRIPTION OF THE SOLUTIONS

For the engineering management of the contaminated sand in the natural beach, three potential solutions were studied: a) removal of the total sand volume for treatment in an external aggregate plant for its subsequent use as construction material within the works; b) dredging and offshore dumping of the total sand volume (i.e. disposal in open sea) and c) partial removal and reuse of a part of the total volume as material for the filling process of the geotextile tubes. The use of ‘closed’ geosynthetics systems (i.e. geotextile tubes) represented not only a solution for conforming the breakwaters cores, but also a complementary straightforward method for ensuring the long-term confinement and controlled encapsulation of a considerable volume of contaminated sand (avoiding particle mobility and direct contact with the environment), which derived in important technical, environmental and economic advantages for the project (e.g. cost and time reduction due to the optimization of required rock volume and number of truck operations, among many others). The removal of 1,0 m depth layer of the contaminated natural beach sand was then considered at the first activity of the works, resulting in an estimated volume of ~29.000 m^3 of sand with the potential to be reused in the construction of the coastal protection structures cores. The design of the coastal protection structures included two main breakwaters: one located in the north side with 120 m of length, and the other in the opposite side 199 m long (both in arch arrangement). As mentioned before, the inner layer of these two structures (breakwaters core) was designed considering geotextile tubes filled with the contaminated sand extracted from the beach and pumped within these units. Over the geotextile tubes different protection layers of rock material were carefully designed according to stability, construction and durability requirements. In addition, the implementation of a central submerged breakwater entirely built with rocks was planned, aimed to conclude the semicircular closure formed between the two arches of the lateral main breakwaters (See Figure 2). Geotextile tubes filled with contaminated local sand were conceived in arrangements of 1, 2 and 3 levels according to the geometric general design in trapezoidal configuration of the breakwaters, being installed under very adverse conditions of waves water depths (~5 m). These solutions combined with the placement of 26.000 m^3 of clean white imported sand allowed to create a new beach area 250 m long.

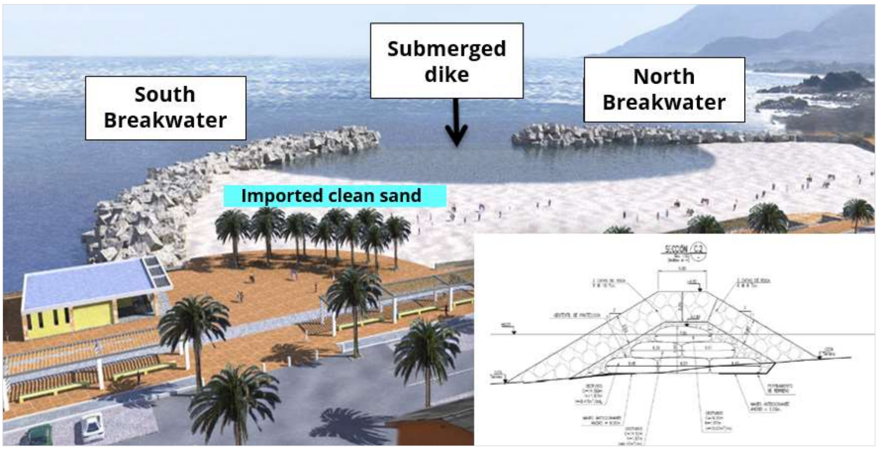

Figure 2. General concept of protection structures and artificial beach – Breakwater cross section

3. DESIGN ASPECTS

At the base of each geotextile tube trapezoidal arrangement, geotextile scour aprons were properly design based on hydraulic erosion actions. Each of these elements consisted in a panel of high tensile strength woven geotextile (6 m width x 22 m in length) connected to anchor lateral geotextile tubes (with 2 m of circumference) and with separation of at least 2,5 m with respect to geotextile tubes core toe (Figure 2). The geotextile tubes were designed with Circumferences varying from 10,5 to 16,5 m and Lengths from 15 to 20 m. All the geotextile tubes were confectioned with a high tensile strength polypropylene geotextile (biaxial nominal tensile strength of 200 kN/m according mechanical calculation). The puncture resistance of the geotextile as well the seam strength of the tube itself were carefully selected according very strict project requirements. Other important properties of the geotextile material also had to be defined as part of the design stage. In this manner, a characteristic opening size of 0,30 mm was selected for the geotextile (according to ISO 12956) in correspondence with the verification of the retention and filtration criteria required for this case (Bezuijen & Vastenburg, 2013), considering a maximum diameter of ~0,32 mm for the particles of the filling material. Finally, a minimum level of UV radiation resistance was estimated for the geotextile of the tubes (i.e. residual tensile strength ≥ 80% after 4.300 hours of exposure) in accordance with the standard DIN EN 12.224). The two main breakwaters were conceived in order to conform a defense barrier reaching a final level of +4,5 meters above sea level. The designed position and geometry of each structure allowed to counteract efficiently the effect of predominant ocean currents (parallel to the coastline). Also, the configuration of each of the layers of the breakwaters (mainly the external coverage) enabled to satisfy a condition of stability for a design wave height of ~ 3,5 m.

4. CONSTRUCTION METHODS

The installation, filling and stability of the geotextile tubes was one of the critical points of the project given the difficulties caused by the extreme tidal and waves conditions. As a result of a real scale test carried out by the contractor in the first stages of the works, the construction of a complementary rock barrier protecting the work area (as a ‘working’ dike) was defined and implemented. A crane of 13 tons of capacity was also used for the operation of an innovated metallic frame structure that facilitated not only the geotextile tubes filling process under water (i.e. acting as ballast element), but also the placement of external dike rocks. For the extraction of the contaminated local sand, a special pump with a suction capacity up to 65% of solids content and a pumping flow rate of 220 m³/h was employed. Once the tubes filling process was finalized, an additional protection geotextile (non-woven with a unit weight of 500 g/m²) was placed covering the tubes surface. Above this geotextile a filtration rock layer (300 to 500 kg elements) was installed, followed by an external protection armor rock layer as revetment (with elements from 2 to 4 ton of weight).

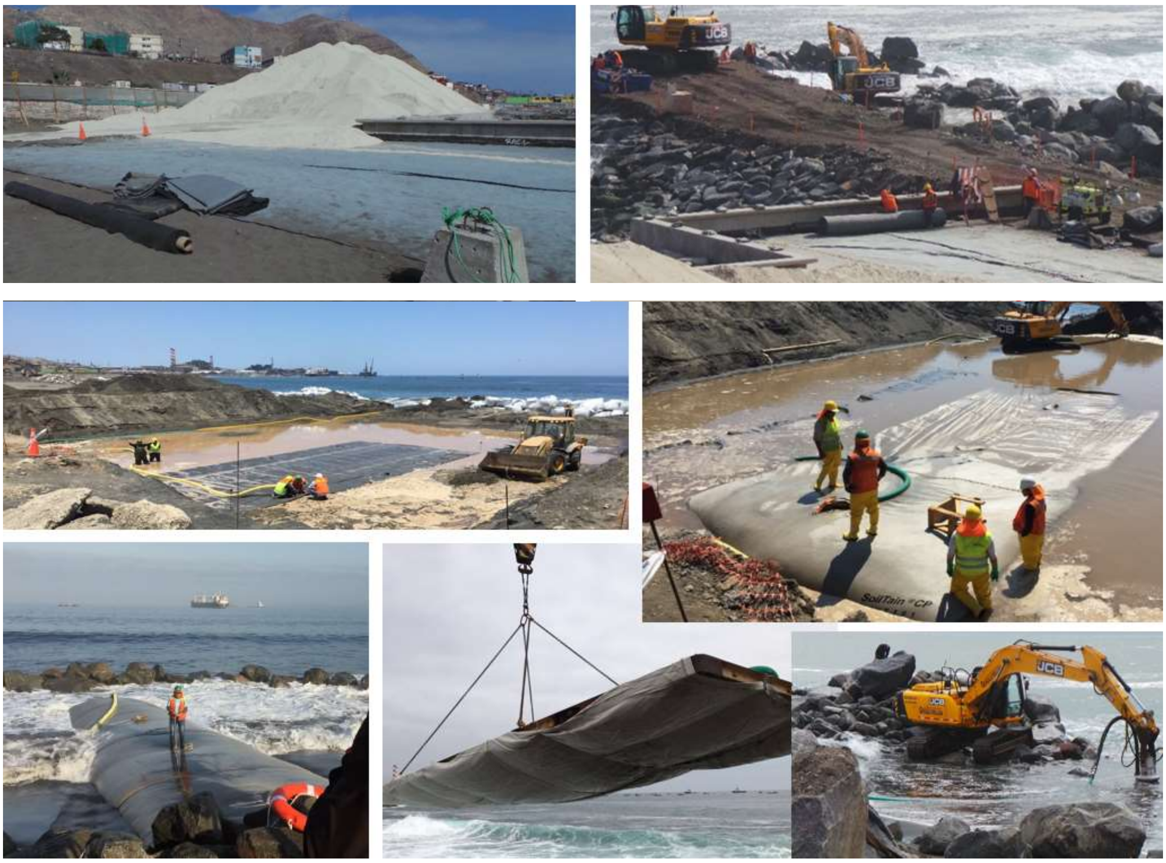

Figure 3. Construction detailed sequence

5. FINAL REMARKS

The implementation of the project represented a satisfactory environmental and economic solution for the tourism and recreational development of Tocopilla city. The efficient and balanced use of natural materials combined with state-of-the-art geosynthetic technology made possible to overcame a significant number of technical difficulties given the complex natural hydraulic conditions of the area. Technical challenges were also properly tackled both in the design stage (e.g. use of different methodologies for various actions cases, adequate selection of the properties and dimensions of required geosynthetic materials), as in the construction phase (adaptability by the use and development of special techniques and equipment, work in limited 'windows' given by the tidal level, etc.). Outstanding engineering effort, construction flexible innovation procedures and high quality geosynthetics materials enabled to provide a renovated environmentally friendly coastal area to the local population.


Figure 4. Aerial view of 'El Salitre' Artificial beach.