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Construction supervision of bamboo fences in Bac Lieu Province, Vietnam

Coastal Forest and Ecosystems Management

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1 INTRODUCTION

Most of the dynamic coastline of Soc Trang Province and Bac Lieu Province in the Mekong Delta of Viet Nam is protected from erosion, storms and flooding by a narrow belt of mangroves. However, the unsustainable use of natural resources in the coastal zone is threatening the protection function of this forest belt. This is exacerbated by the impacts of climate change, particularly the increased intensity and frequency of storms and floods, and by rising sea levels. In sites where severe erosion has destroyed the mangrove belt, coastal protection and climate change adaptation through mangrove rehabilitation is only possible after the wave energy has been reduced by physical barriers. This can be achieved with breakwaters and T-shaped fences, which reduce erosion, stimulate sedimentation and based on their placement and design avoid downdrift erosion as far as possible.

A breakwater and several T-shaped fences have been established for one area of the coast of Soc Trang, which is subject to severe erosion, based on a numerical model simulating hydrodynamics and shoreline development (ALBERS & VON LIEBERMAN, 2011). Field measurements have been used to understand the morphodynamic processes and to verify the model. Different arrangements, placements and designs of erosion protection measures, which are a prerequisite for mangrove rehabilitation in erosion sites, were investigated using numerical and physical modelling. The effectiveness of conventional breakwaters as well as different designs using local materials was tested. Bamboo breakwaters and fences yielded the best results and have additional advantages due to the strength, availability and low cost of bamboo. The results of the study were transferred to the coast of Bac Lieu Province.

In May 2012 500 m bamboo fences have been built at the coast of Bac Lieu. This report describes the construction site, the construction itself including preparation, materials and installation and summarises the main aspects of the construction supervision and the proposed monitoring programme.

In a second construction phase in Bac Lieu Province this sustainable erosion protection will be continued and more 1,000 m bamboo fences will be built. The monitoring of the already existing structures will be continued and complemented.

2 CONSTRUCTION SITE

In the frame of a baseline study in December 2011 different locations along the coast of Bac Lieu Province were evaluated concerning erosion (ALBERS, 2012B). In the area around location 4, approximately 5 km southwest of the border to Soc Trang Province, local erosion occurs (Figure 1). This location has been chosen as the first construction site for the bamboo fences (Figure 2).

Figure 1: Local erosion at location 4

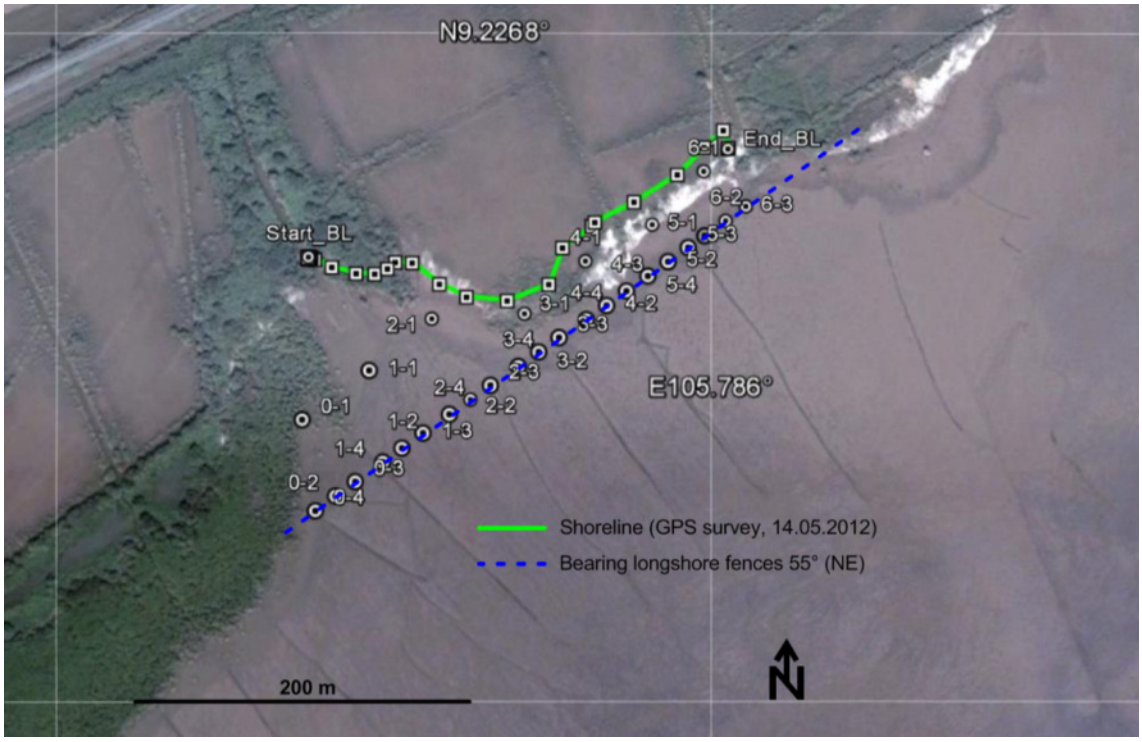

Figure 2: Site map of the T-shaped bamboo fences

The goal of the construction is to close the existing headlands and to establish wider flood-plains on which the wave energy is reduced. The position and the bearing of the longshore fences result from the existing headlands. Thus, its bearing from southwest to northeast is 55°. During the on-site inspection on May, 14th the shoreline has been recorded using a standard GPS.

At the construction site seven T-shaped fences have been defined (Figure 3). During the on-site inspection and definition of the fences on May, 14th the positions of the fences were marked. The length of the longshore parts is 30 m. According to the water depths and the wave loads at location 4 the normal width of the gaps has been set to 20 m. The two eastern-most gaps have been adapted according to the situation on site (distance to the headland). The cross-shore parts lead to the current shoreline, up to where the density of the mud increases observably. The bearing of the cross-shore fences results from the bearing of the dyke, the main wave directions and the main tidal current directions. The bearing from north to south is approximately 155°.

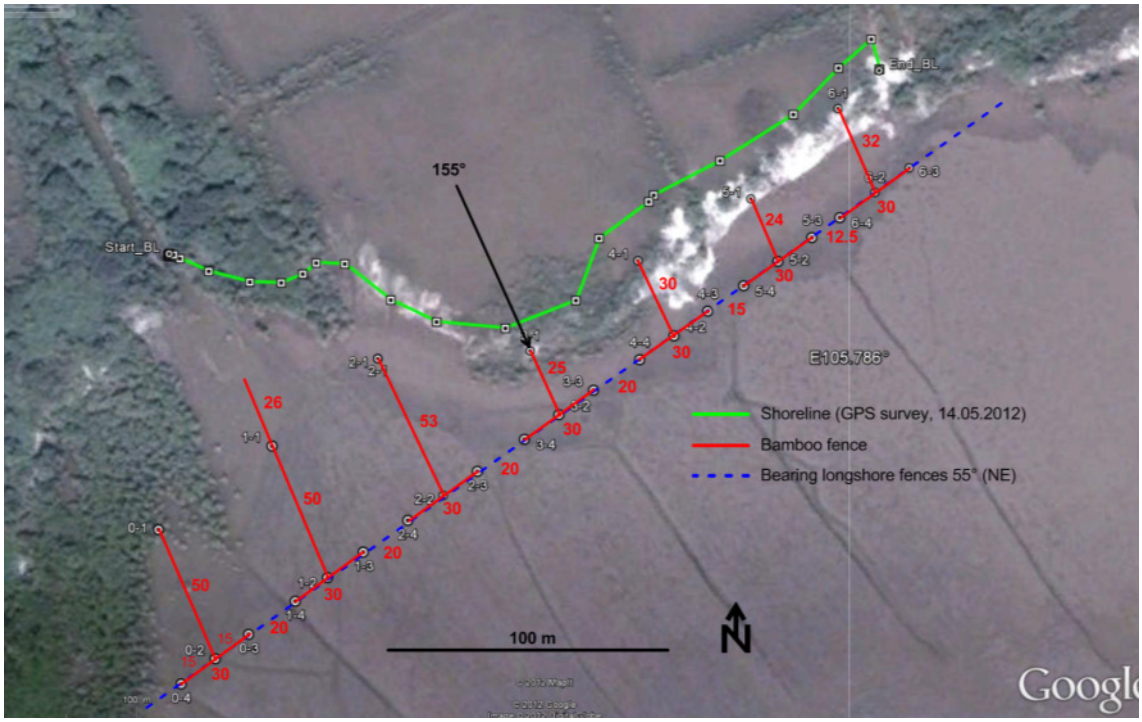

Figure 3: Arrangement of the T-shaped fences

3 CONSTRUCTION

3.1 Preparation and site facilities

Before the construction, the positions of the fences (landward and seaward end of the cross-shore parts and both ends of the longshore parts) have been marked. Therefore, a standard GPS receiver was used. Due to the accuracy of the GPS additionally a compass and a measuring tape were used to cross-check the bearings and the distances. Directly before the installation of the vertical piles a cord was spanned between the marks to define the axis of the structure.

The materials were delivered to the dyke by trucks. From here workers transported the bamboo and the bundles over a distance of 200 m to the site. The transport turned out to be a bottle-neck after heavy rainfall due to the soaked surface of the soil. Adapted to the weather conditions and the material demand teams of 4 to 10 workers were used to keep up the work flow. In the first days of the construction it was tried to use a barge to transport materials from a bridge at the dyke to the construction site. Due to the low water depths in that area, this idea was rejected.

A temporary place for the storage of the bamboo, the bundles, the connection material and the tools needed for the installation was set up at a higher position on the remaining floodplains at location 4 (Figure 4).

Temporarily a barge was anchored at the construction site to provide catering for the workers.

Due to the chosen installation method no further site facilities were necessary.

Figure 4: Temporary storage place

3.2 Materials

3.2.1 Bamboo

During the construction the length and the diameter of numerous bamboo poles was measured (Figure 5). The mean diameter of the poles was 69.5 mm. The mean length was 3.00 m. Thus, the length and the diameter of the bamboo poles fulfilled the requirements of the tender. The characteristics of the used bamboo exceeded the values assumed in the design of the structure (ALBERS, 2011).

A pre-selection war carried out at the temporary storage place: Very straight bamboo poles with a diameter around 60 mm were selected to be used as horizontal bars.

Figure 5: Measurement of the diameter of the installed bamboo

3.2.2 Bundles

For the bundles smaller bamboo branches were tied up (Figure 6, left). The length of the bundles was between 2.00 m and 2.50 m.

The dimensions, density, permeability and the flexibility fulfilled the requirements of the tender documents.

Additionally Nypa leaves were delivered for the installation in the bamboo fences (Figure 6, right).

Figure 6: Bundles (left), Nypa leaves (right)

3.2.3 Connection material

In the tender documents the connection material was defined to be rattan. This material was also used during the construction of the sample section in December 2011 (ALBERS, 2012A). Before the construction started, the contractor mentioned a problem with the tendered material: Rattan with the required quality is hard to find in sufficient quantity, available rattan is of poor quality. In a site consultation meeting on May, 16th alternatives were discussed. Nylon lines were refused due to the low inner friction, the poor handling and especially the short durability (in UV light). Jute rope was agreed upon (Figure 7). It is a natural product and its advantages are:

- High tensile strength
- High durability
- Good handling
- Availability

Figure 7: Jute rope

3.3 Installation

3.3.1 Transportation of materials

For the construction of the fences the bamboo and the bundles were brought from the temporary storage place on the floodplain to the site of installation just in time. They were carried or pulled by the workers through the mud or water. Especially during low water when the mudflats fell dry this was a hard and time consuming work in the mud (Figure 8). While the water level was high enough materials were floated out to the site of installation.

Occasionally a long-boat was used to bring larger amounts of bamboo and bundles to the site of installation (Figure 9). This was a fast and more convenient way of transportation.

Figure 8: Transport of the bamboo and the bundles through the mud

Figure 9: Transport of materials using a long-boat

3.3.2 Vertical poles

The vertical poles were installed manually. After being transported to the site of installation, they were put into the right position and adjusted along the cord. First they were stuck into the mud as deep as possible. Afterwards teams of three to four workers pulled the poles down to the required depth using their own weight. Therefore a rope or belt was attached to the bamboo pole and another bamboo poles was stuck through the loop that formed the other end of the belt or rope. Then, the workers stood on the horizontal poles and pulled the vertical poles into the mud (Figure 10). This procedure was similar to one of the installation methods executed at the sample section in December 2011 (ALBERS, 2012A).

Using only this technique no further tools were needed. The progress depends on the properties of the mud surface and on the team of workers. At the construction site of the fences the mud was not too deep and the progress accelerated after the first days. Anyway, some of the teams coordinated their work well and were obviously faster than others.

Material supply was crucial for the progress. Especially in the first days of the construction the progress of the installation of the vertical poles decelerated due to a lack of bamboo poles.

Figure 10: Installation of the vertical poles

Due to rests of roots or other items in the soil, some of the poles could not be pulled completed to the depth indicated in the drawings. If this is locally limited, it does not have an influence on the stability of the fences. The contractor was ordered to cut the lap poles on the required level.

3.3.3 Horizontal bars

After installation of the vertical poles the horizontal bars were connected according to the construction drawings. Therefore straight bamboo poles were pre-selected. Teams of two workers first attached both ends of the bars and then fixed the other connections. At the construction site this work could be done almost tide-independent (Figure 11).

3.3.4 Bundles

After installation of the horizontal bars the bundles were put between the two rows of bamboo poles (cf. Figure 12). A man's load was used to compact the bundles. Two or three layers of bundles were installed. The top layer was attached to the horizontal bars and the vertical poles. The bundles should always be installed flush with the vertical poles and must have an open structure with smaller branches.

The nypa leaves with its dense structure of the single leaves were used as the bottom layer of the bundles (Figure 13, left). Thus, they have a function of scour protection at the interface of the poles, the soil and the water column.

For the top layer of the bundles also nypa leaves were used (Figure 13, right). The thick trunk of the leaves is helpful to tie down the bundles and the structure of the single leaves forms a dense closing-off.

Figure 11: Connection of the horizontal bars

Figure 12: Different grades of completion of the fences

Figure 13: Nypa leaves as bottom layer (left) and top layer (right) of the bundles

3.3.5 Connections

The connections of the vertical and the horizontal poles were made using joint lashes (Figure 14). As preparation of the works the jute rope has been cut into pieces of approximately 2.0 m lengths (cf. Figure 7). The connection of the horizontal bars to the vertical poles could be used to adjust the vertical poles to a certain extend.

Figure 14: Joint lashes with jute rope

4 AMOUNT OF MATERIAL

For a detailed analysis of the construction, for an evaluation of the cost-benefit-characteristics of the bamboo structures and for recommendations concerning future construction phases, information about the amount of used materials and the number of working hours are essential.

At fence number 2 the quantity of vertical bamboo poles has been counted after installation. There were 293 poles on a 50 m section. This results in 5.86 poles per meter. Since the length of the used bamboo poles was 3 m, per running meter 2/3 of a pole has to be added for the horizontal bars. This results in 6.53 poles per meter including the horizontal bars.

Upon completion of the construction the further information should be derived from the closing invoice of the contractor or should be directly requested or determined. The information will be analysed and this chapter will be updated.

The following information are required:

- Total number of used bamboo poles (if that information is available)
- Approximate length of used jute rope (number of bundles)
- Number of used bundles
- Number of working hours
- Number of employed workers and the distribution over the construction time

5 CONSTRUCTION SUPERVISION

The construction supervision was carried out as the most important measure of quality control. The presence of the supervisor was essential to assure a sound installation and a timely completion. The construction progress and the schedule of material supply and further construction was requested and discussed with the contractor regularly. All details mentioned above and indicated in the construction drawings were controlled continuously:

- Marking and repeated control of the positions and the bearings of the fences using GPS, measuring tape and compass (incl. cross-check)
- Control of the straight installation of the fences along the bearing of the marked positions (using cord between the marks)
- Control of the bamboo (diameter, length, curvature)
- Control of the bundles (diameter, length, density, connections)
- Control of the vertical poles (straight installation, distance between poles and rows, depth of embedment)
- Control of the cutting of the top of the vertical poles (where applied)
- Control of the horizontal bars (diameter, overlapping length)
- Control of the bundles (connections to the horizontal and vertical poles, installation flush with vertical poles)
- Control of the connections (every vertical pole must be connected to the horizontal bars, tight connection)

6 MONITORING

To be able to assess the effectiveness of the bamboo structures quantitatively, a comprehensive monitoring programme is appreciated. Already during the construction phase in Soc Trang Province a monitoring programme was set-up and started. An additional monitoring of the bamboo fences in Bac Lieu Province can provide further important information.

The proposed monitoring of the bamboo fences includes:

- Visual control
- Photo documentation
- Benchmarks
- Monitoring of mangroves
- GPS shoreline survey

Visits to the fences in the frame of the monitoring should be carried out approximately every 4 weeks. The regular monitoring interval has to be adapted to the situation and for example reduced in case of extreme events. As soon as possible after storm surges and storms all steps of the monitoring programme have to be carried out. That visit has to be followed by another control approximately one week after the event. A photo documentation during a storm surge (from the floodplain, if the water level allows it) is of large interest.

All steps of the monitoring have to be documented in an appropriate from including date, time, tidal conditions etc.

6.1.1 Visual control

The visual control should include all details that were described above:

- Vertical poles: control of embedment, note damages and scours, evaluation of general status, control of stability
- Horizontal bars: note damages, evaluation of general status, control of stability
- Bundles: evaluation of the status of the materials, control of connections
- Connections: general control of all connections and its tightness, evaluation of the status of the jute rope
- General observations at the fences, the surrounding mudflats and the floodplains (e.g. large floating items)

6.1.2 Photo documentation

In the frame of a photo documentation in general three perspectives should be covered:

- Overviews from fixed positions (defined x- and y-coordinate, height above surface, direction, angle, zoom factor) at a higher position on the floodplain as well as near the fences showing the general development of the mud flats and the floodplains
- Detail views from fixed positions near the fences showing the development of details such as scours, connections etc.
- Photographs of special observations from free positions

6.1.3 Benchmarks

Figure 15 proposes the positions of four benchmarks (I-IV). The benchmarks indicate the development of the mud level. They are constructed from straight wooden poles including mechanical marks (kerfs) in distances of 5 cm covering a length of approximately 1.00 m. The zero value, which has to be marked differently, will be installed on the current mud level. The marks reach up to 0.4 m below mud level and 0.6 m above mud level. The total length of the benchmark pile should be 3.0 m whereas the depth of embedment is 2.0 m.

According to Figure 15 benchmarks I and II indicate the changes of the mud level in the field between fences number 1 and 2. Benchmarks number III and IV indicate the changes in the field between fences number 4 and 5. Thus, independent data of different fields at the western end and the eastern end of the site are provided. The different mean wave directions due to the monsoon seasons are taken into consideration using positions of the benchmarks on the east and the west side of the fences.

6.1.4 Monitoring of mangroves

At the time of construction in the surroundings of the breakwater many young mangroves were found (Figure 16). Those mangroves can be used as an indicator for the influence of the fences. For example, transects at the construction site can be defined to carry out a mangrove monitoring. The exact position of the transects and the detailed procedure have to be defined by the GIZ project.

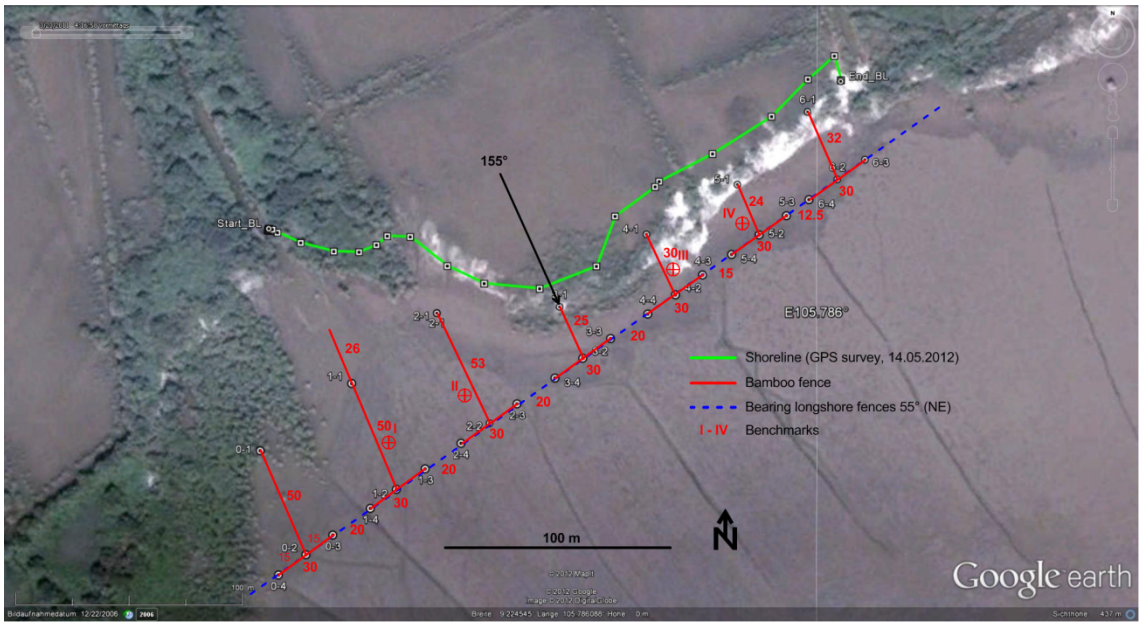

Figure 15**:** Location of the benchmarks

6.1.5 GPS shoreline survey

The GPS shoreline survey records the course of the shoreline. The initial shoreline that is indicated in Figure 2 and 3 has been surveyed on May, 14th. The measurement should be repeated in semi-yearly intervals. The accuracy of the standard GPS but also subjective variations in the definition of the shoreline, especially in the area between fences 3 and 5, do not allow a more detailed survey in intervals of one or two months that record changes with the magnitude of decimetres. The shoreline survey should be carried out and repeated by the same person and be geared to the initial survey to keep the same definition of the shoreline.

Figure 16**:** Young mangroves at the site of the fences

7 RECOMMENDATIONS AND LESSONS LEARNT

Based on the experiences of the construction phase in May 2012 recommendations for future constructions can be given. Additional to the details mentioned in the previous chapters, here important lessons learnt are pointed out:

- The final arrangement of the fences has to be done on-site (not based on older aerial views).
- The marks of the fences have to be set by means of GPS, compass and measuring tape – not only GPS.
- A temporary storage place for the materials must be defined near the site of installation.
- The logistics of the construction are crucial. Steady material supply is essential. Therefore the conditions of the paths leading to construction site need to be taken into consideration.
- In the rainy season the accessibility of the soil paths is limited and decelerates the construction progress.
- The water depths at the construction site need to be checked in advance. If material transport from one of the bridges at the dyke to the site with barges is possible, this may accelerate the construction progress significantly.
- The bamboo poles have to be straight to allow a sound installation.
- A pre-selection of the bamboo poles should be carried out at the temporary storage place. Straight poles with a smaller diameter should be used as horizontal bars.
- The maximum length of the bundles should be between 2.0 and 2.5 meters due the weight and the handling.
- The percentage of split bamboo or rougher bamboo branches in the bundles must be limited. The structure of the bundles should be as described in the design documents (ALBERS, 2011). Only bundles with an open structure, a lower density and a larger percentage of smaller branches reach the desired wave attenuation and can be fixed properly.
- Especially the connections of the bundles of the longshore fences are crucial and have to be controlled continuously.

- A sound organisation of the transport from the temporary storage place to the site of installation is important. The use of boats or rafts – while the water level is still high enough – saves time.
- A sound organisation of the work flow is essential for a timely completion of the construction.
- A manual installation of the vertical poles is possible. Its timely and sound realisation depends on an adequate organisation of the work flow and the material transport. At the site of the fences where the mud is not too deep and the water levels are not too high the manual installation is recommended. Additional tools such as a head ram can be helpful but are not essential. More important is a sufficient number of workers.
- The coordination of the teams of workers and the selection of experienced workers as leaders improve and accelerate the completion.
- An experienced foreman improves and accelerates the completion.
- The measures of construction supervision described in chapter 5 are of large importance and should be carried out during the entire of the construction.
- The accomplishment of the monitoring programme as describe in chapter 6 is appreciated and will provide important information.

Figure 17**:** Completed fences

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