Management of Natural Resources
in the Coastal Zone of Soc Trang Province

Installation of bamboo fences

Thorsten Albers

Deutsche Gesellschaft
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1 Introduction

The coastal areas in Viet Nam’s Mekong Delta are characterised by the discharge regime of the Mekong River as well as by the tidal regime of the Vietnamese East Sea. Most of the dynamic coastline of Soc Trang Province in the Mekong Delta 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 protective function of this forest belt. The northeast monsoon causes an increased coastal long shore drift, which causes strong erosion at different coastal sections. It is most likely that climate change, particularly the increased intensity and frequency of storms and floods and rising sea levels will intensify erosion and increase the demand for sustainable erosion protection management.

It is the overall goal of the GIZ project, Management of Natural Resources in the Coastal Zone of Soc Trang Province, to protect and sustainably use the coastal wetlands of Soc Trang Province for the benefit of the local population.

In previous studies executed by the Hamburg University of Technology and von Lieberman GmbH, 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. Available data with relevance for the coast of Soc Trang were researched and analysed. Additional field measurements were carried out to understand the hydrodynamic and morphodynamic processes in the focus area of Vinh Tan and to verify results of the numerical modelling. The results of both the field measurements and the numerical modelling were used to design sustainable countermeasures. After approval of these countermeasures by the Provincial People’s Committee, detailed design documents were prepared for a construction tender.

The tender was not successful because Vietnamese construction firms have never before used water pressure and steel lances to install bamboo poles in the hard sand of the coast.

Using the expertise of Mr. Thorsten Albers, who did the numeric modelling and the design of the breakwaters, a sample section of a bamboo fence was constructed so that Vietnamese construction firms can learn the technique of how to install bamboo poles using different techniques including water pressure.

All steps of the installation and construction were documented and are summarised in this report.

The construction of the bamboo breakwater and bamboo fences in Vinh Tan serves as a pilot project for erosion protection and mangrove rehabilitation in erosion sites, which will also be used to gain knowledge for future application and optimisation through detailed documentation and monitoring.

Tension tests have been carried out and were documented to quantify the strength of the embedment. A detailed monitoring programme for the effectiveness of the breakwater and bamboo fences was developed and initial data collection started.

2 Construction Site

2.1 Site maps and description

In the lee area of the breakwater (related to the main wave direction) the construction of bamboo fences was recommended (Albers & von Lieberman, 2011). The heading of the cross-shore fences is 161°; the heading of the longshore fences is 71°. The cross-shore fences start at the revetment of the dyke and form three main fields (Figure 1).

Figure 1: Site map

For the sample section of the bamboo fences, the longshore component of the westernmost main field was chosen (cf. Figure 1).

The development of the detailed design (ALBERS, 2011) and the construction phase morphologic changes occurred at the coast of Vinh Tan since the last measurement campaign in July 2010. Fluid mud filled up the area in front of the dyke. The brim between the revetment and the top ground surface of the mud disappeared. Now the surface of the mud is approximately at the same elevation as the revetment. Starting at the dyke, the first 20 to 25 m of the mud is relatively solid and walkable. Then it becomes fluid with a depth of approximately 1 m followed by a more solid walkable layer of consolidated mud underneath.

Before the construction, it was agreed that the design and the construction plan be kept, with the aim of stabilising the present situation. The bamboo fences and the breakwater help to consolidate the fluid mud. So a re-planting of mangroves in the area protected by the bamboo structure will be possible earlier than assumed in the original concept due to the temporary sedimentation which occurred without wave breakers. A complete construction of the bamboo structures as indicated in Figure **1** will anticipate the morphologic development that is described in the report "Current and Erosion Modelling Survey" (ALBERS & VON LIEBERMAN, 2011). Therefore, the construction should continue in the near future with some adaptations made to the design of the fences and wave breaker.

As a consequence of the consolidated mud in front of the dyke, the position of the sample section was shifted further offshore than originally planned. The lengths of the cross-shore fences were adapted accordingly. It was assumed that they will connect to the revetment. It will be decided during the construction if this is really necessary for stability reasons.

Figure 2 shows the sample section of the bamboo fence after construction. The photo was taken from the dyke.

Figure 2: Sample section of the bamboo fences at Vinh Tan

2.2 Front views and cross sections

Figure 3 - Figure5 show front views and cross sections of the sample section. Compared to the drawings in the report “Design of breakwaters” (ALBERS, 2011) some adaptations were made based on experience during the sample construction:

- The distance between the vertical poles is approximately 0.35 m. Most of the bamboo poles are not straight and this value therefore has a tolerance of ± 0.10 m. Putting the poles close together is not possible due to their form and the construction process. However, this is not necessary because of the high load capacity of the poles which are embedded for 2/3 of their length.
- The lower horizontal bar is installed at the mud surface level. This turned out to be the easiest way of installation and does not change the statics.
- The crests of the vertical poles are not on a single level as indicated in the drawings (ALBERS, 2011, attachments 5 and 13). This is because of the difference in lengths of the poles and different soil conditions. However, the depth of embedment is large enough and it is therefore not necessary to cut the crests of the poles to the same length (see Figure 29 and Figure30).
- The distance between the two rows of vertical poles is approximately 0.5 m and also has a tolerance of 0.10 m due to the characteristics of the material.
- Depending on the degree of compaction, 5 or 6 bundles were used between the two rows of bamboo poles.

Figure 3: Front view; landward side of the bamboo fence

Figure 4: Cross section and seaward side of the bamboo fence

Figure 5: Cross section of the bamboo fence

2.3 Connections

Figure 6 – Figure 8 show the connections of the horizontal bars to the vertical poles made from rattan stripes. The connections were made by workmen hired locally and carry a man's weight without any problem.

When it is very dry, the rattan becomes fragile. The tide and the waves keep this from happening and the mud provides further protection.

Figure 6: Side view of the bamboo fence

Figure 7: Connection of the horizontal bar to the vertical poles

Figure 8: Joint made with rattan stripes

3 Construction Process

3.1 Preparation and site facilities

A temporary place for the storage of the bamboo, brushwood, connection material and tools needed for the installation was set up behind the dyke for the construction phase of the sample section. For the construction works, a fishing boat and a long-boat were chartered and used as a working base (Figure 9). They were kept at the installation site during the entire construction phase.

The brushwood was roped into bundles before being brought to the installation location. The bundles and the bamboo were carried to the installation location by hired workers (Figure 10 and Figure11). Floating objects such as polystyrene boxes were used to make transport through the fluid mud easier. The number of bamboo poles and bundles brought to the construction site was sufficient to have material for a half day.

Figure 9: Long-boat used during the installation

Figure 10: Material transport (bamboo) to the construction site

Figure 11: Material transport (bundles) to the construction site

The use of wooden walkways to improve the accessibility through the mud was tested during the sample construction (cf. Figure 12). The walkways were assembled at the dyke and brought to the construction site during high tide. For the first one or two hours they helped to walk and work in the mud, but afterwards they sank into the mud and could not be used any more.

Figure 12: Wooden walkways to improve the accessibility of the mud

Figure 13 shows the cutting of excess material from the bamboo nodes. This cutting is recommended because the smoother poles can be installed more easily. The cutting can be done on land, but also directly at the construction site.

Figure 13: Cutting of excess material from the bamboo nodes

3.2 Installation

The installation process consists of three distinct steps: (1) installation of the vertical bamboo poles, (2) installation of the horizontal bamboo poles and (3) putting the brushwood bundles in place.

3.2.1 Installation of the vertical bamboo poles

During the installation of the vertical poles, four different installation methods were used and documented.

1. Using a sledge hammer. Figure 14 shows the installation of the vertical bamboo poles using a sledge hammer. This method is only applicable when a high and secure standing position is available (e.g. if a boat is used as a working platform). Due to the length of the poles, the sledge hammer is only applicable for the last part of the installation. Furthermore, the installation method is exhausting and is only recommended for special situations when it is necessary to apply a very high force onto a small spot.

2. Using a head ram. Figure 15 - Figure17 show installation using a head ram. The head ram can be used by two or four people. This method can be applied directly after the bamboo pole has been pushed into the mud by hand as far as possible. It can be used to install the poles completely due to the fluid characteristics of the mud (the handles of the head ram can be pushed easily into the mud). It even can be applied under cramped conditions, e.g. when the second row of poles is installed.

It is recommended that the diameter of the ram's tube is 2 or 3 cm larger than the largest diameter of the bamboo poles to make the handling easier. The length of the tube should be a few centimetres larger than during the installation of the sample section (cf. Figure 18). Especially for a team of two workers the use of the head ram is the most suitable installation method.

Figure 14: Installation using a sledge hammer

Figure 15: Installation using the head ram with two people

Figure 16: Installation using the head ram with four people

Figure 17: Installation of the second row using the head ram

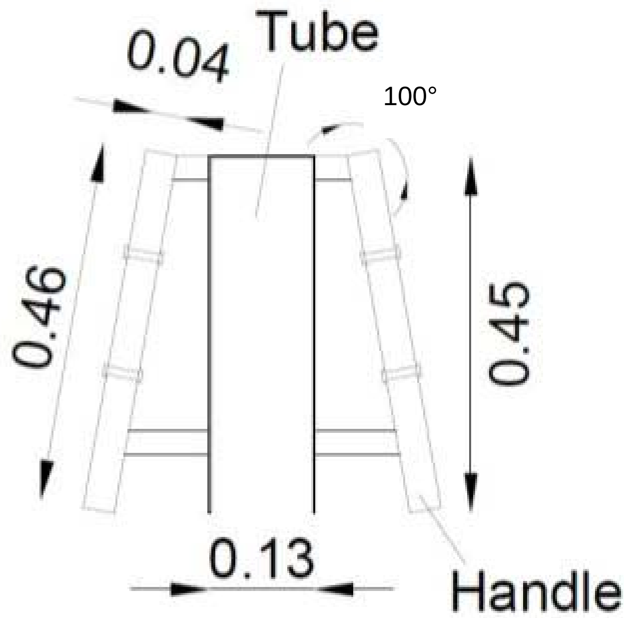

Figure 18: Sketch of the head ram

3. Using pressing technique. Figure 19 – Figure 22 show the installation of the vertical bamboo poles using a pressing technique. For this a belt is fixed around the vertical pole, ideally directly above a node. Then, a smaller bamboo stick is put through the loop created by the belt and the weight of the workers is used to push the bamboo poles down. This method is even applicable under cramped conditions.

During the construction, this method turned out to be favoured by the workers. It was quick and accurate and it was even possible to install the poles at positions with some local discontinuities in the soil.

Figure 19: Installation using pressing technique with horizontal bar

Figure 20: Fixing of the horizontal bar

Figure 21: Installation using pressing technique with horizontal bar

Figure 22: Installation of the second row

4. Using water pressure. In general the easiest way to install the bamboo poles is to use water pressure. This requires a vessel with electricity, a pump and water. The installation has to be done during calm weather conditions and with adequate water levels to move the vessel along the breakwater or fence. Alternatively a water tank can be held available on the vessel during low water. During the construction phase of the sample section, the water levels were too low. For demonstration of this installation method a test pole was installed at a sluice gate near the construction site.

An immersion pump with a delivery height of 75 m was used (Figure 23). A hose was attached to the pump; the end section of the hose was a hollow steel lance. One worker held the pole while another worker controlled the lance and pushed it into the soil in parallel with the bamboo pole (Figure 24). Due to liquefaction of the surrounding soil at the head of the lance, the bamboo pole can be pushed into the soil with little pressure. Then the lance can be pulled out. A movement of the lance (up and down) increases the grade of liquefaction and makes it easier to plunge the pole.

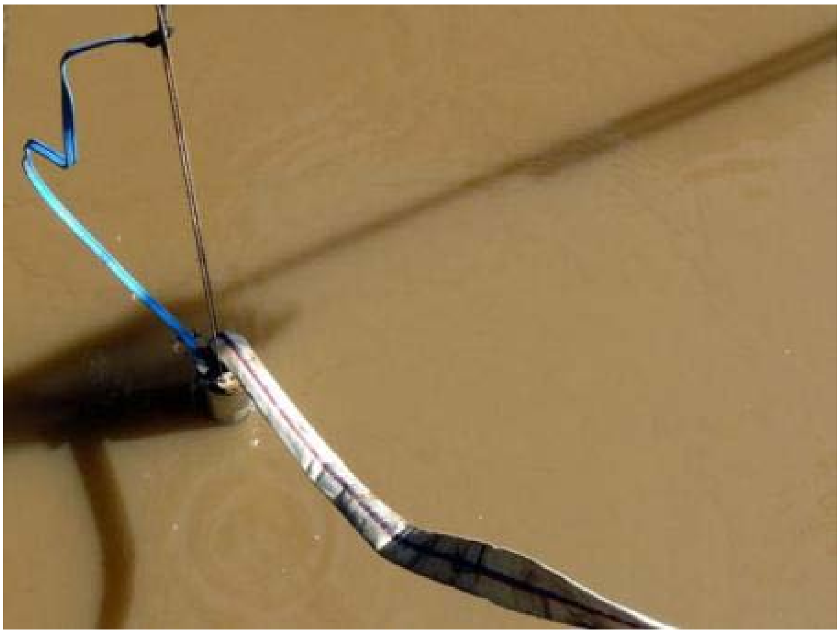

Figure 23: Immersion pump

Figure 24: Installation using water pressure

This installation method is only applicable when enough water is available. Moreover it uses technology that is more susceptible to interference than the first three installation methods. However, if the equipment (including an adequate vessel or pontoon) is available, if the work flow is structured and if the workers are skilled, installation using water pressure is suitable to install a large number of bamboo poles per day.

5. Using dredger on pontoon. This method was not tested but is described in section 7 on pages 41 to 42.

3.2.2 Installation of the horizontal bamboo poles

After the installation of the vertical bamboo poles, the horizontal bars were attached to the vertical poles with rattan stripes (Figure 25 - 28). With the connection of the horizontal bars it was possible to adjust the line of vertical poles. First the horizontal bars on the mud surface level were installed. The connections at both ends of the bar were prepared followed by the rest of the connections. Afterwards the upper horizontal bars were connected in the same way.

Figure 25: Fixing of the horizontal bamboo poles

Figure 26: Connection of the horizontal bamboo pole

Figure 27: Preparation of the connections

Figure 28: Preparation of the connections of the upper horizontal pole

3.2.3 Putting the brushwood bundles in place

After installation of all bamboo poles the brushwood bundles were put between the bamboo poles and compressed by man's weight (Figure 29 and Figure 30). Then the bundles were connected to the horizontal bars. The compression of the bundles was carried out after each layer of bundles. Depending on the compressibility of the brushwood, 5 or 6 layers of bundles were installed.

Figure 29: Installation of the bundles

Figure 30: Installation and compacting of the bundles

4 Amount of Material

Table 1 summarises the amount of material for the construction of the bamboo fences and the bamboo breakwater. Each bamboo pole of the longshore elements and the breakwater has a diameter of 0.08 m. Each bamboo pole of the cross-shore elements has a diameter of 0.06 m.

Table 1: Amount of bamboo for the fences and the breakwater

	Bamboo breakwater	Bamboo fence (longshore)	Bamboo fence (cross-shore)
Vertical poles per metre [-/m]	6	6	6
Horizontal poles per metre [-/m]	8/9	8/9	8/9
Length [m]	100	140	379
Number of poles [-]	689	965	2,611

The numbers in Table 1 are based on the construction of the sample section. The real numbers can vary due to the shape of the poles and the characteristics of the soil.

Rattan turned out to be the best solution as connection material. There are 12 connections of the vertical poles and the horizontal bars per metre fence or breakwater. For each connection, a length of ~ 3 m of rattan is required. With a total length of the breakwater and the fences of 619 m, a total length of ~ 22,284 m of connection material is needed.

To connect the bundles to the horizontal poles, an additional length of approximately 12,380 m of connection material is required. This figure is based on 6 bundles on top of each other and a required length of 10 m connection material per metre breakwater or fence (3 bundles are always connected together).

With a length of a bundle of 2.00 m and an average of 6 bundles on top of each other, approximately 1,860 bundles are needed. Two pieces of rope about 5 m in length each are required for each brushwood bundle. Therefore, a total length of 18,600 m of rope is required for the bundles.

Table 2 summarises the total quantity of building materials for the construction of the bamboo fences and the breakwater.

Table 2: Total quantity of building materials for the bamboo fences and the breakwater

Description	Quantity
Bamboo (Ø = 0.08 m, L = 4.70 m)	1,654 [-].
Bamboo (Ø = 0.06 m, L = 4.70 m)	2,611 [-]
Connection material (rattan)	53,264 [m]
Bundles (Ø~ 0.40 m, L = 2.00 m)	1,860 [-]

5 Construction Supervision

A detailed documentation and monitoring of the construction phase are essential to gain information for future constructions.

The construction supervision must include:

- Visual material control of the bamboo poles, the brushwood and the connection material including photo documentation
- Random measurements of the length and the diameter of the bamboo poles (approximately every 20th pole) including documentation and analysis

- Random control of the bundles (length, diameter, quality, connections) including documentation; measurement of approximately every 30th bundle
- Random control of the connection material; approximately 30 breaking tests
- Control and documentation of the dimensions and positions
- Documentation of the installation method of the vertical poles and additional information, e.g. the number of hits
- Documentation of the thickness of the mud layer
- Control and documentation of the depth of embedment
- Control and documentation of the distances between the vertical poles
- Control and documentation of the inclination of the poles
- Visual control of the connections (vertical poles – horizontal bars, vertical poles - bundles, horizontal bars – bundles) including photo documentation
- Random tensile tests of the vertical bamboo poles; approximately 20 to 30 tests depending on the soil characteristics

5.1 Material control

Table 3 shows the results of the control of the bamboo poles used during the sample construction. A sample of 20 poles was taken out of the total of 104 poles (cf. Figure 31). The bottom and the top diameter were measured. The mean diameter was 83.35 mm (bottom) and 81.30 mm (top), the standard deviation was 7.24 mm (bottom) and 7.91 mm (top). Therefore, the required diameter of 80 mm was reached.

The length of the poles was estimated by measuring one pole and assessing the percentage of shorter and longer poles. Most of the poles (> 85 %) had the required length of 4.70 m. Less than 5 % were shorter and approximately 10 % were a bit longer.

Table 3: Results of the control of the bamboo poles

Sample	**Diameter [mm]**	
No.	**Bottom**	**Top**
1	87	70
2	89	82
3	80	99
4	78	77
5	80	90
6	94	70
7	70	72
8	77	80
9	78	79
10	82	80
11	80	100
12	99	79
13	80	78
14	91	80
15	80	84
16	79	82
17	80	83
18	79	86
19	93	78
20	91	77
Mean	**83.35**	**81.30**
Std. Dev.	**7.24**	**7.91**

Figure 31: Control of the diameter of the bamboo poles

Figure 32: Control of the bundles

The bundles and the connection material (Figure 32 and Figure 33) were controlled visually before the bundles were tied.

Figure 33: Control of the bamboo stripes

5.2 Tensile tests

Tensile tests were carried out to get reliable values for the maximum horizontal forces and information about the failure mechanism (soil or bamboo). The results offer valuable information for further installation of bamboo constructions.

During the construction of the sample section, a series of tensile tests were done at two poles. After the installation a vertical bamboo pole was stressed until failure. An abutment made of a group of three bamboo poles was used for this purpose (cf. Figure 34). Then, a tension belt was clamped between the abutment and the tested pole, and the horizontal force was increased with a belt spanner (cf. Figure 35). The accordant force was measured with a force meter. A standard crane weigher was used as a force meter (cf. Figure 36).

Figure 34: Installation of the abutment for the tension tests

Figure 35: Execution of the tension tests

Figure 36: A standard crane weigher is used as a force meter

Figure 37 shows the results of the tensile tests. They were similar for the two poles tested. When the drag force F was increased, the pole was bent. At a certain point (first maximum) the drag force could not be increased. The soil failed and the pole was shifted between 1 and 2 cm towards the abutment. Then, the situation became stable and the drag force could be increased until the soil failed again. This second maximum was a bit larger than the first one due to the consolidation of the soil in the first test phase. After another test phase, a third maximum was reached, which was higher than the second maximum. During the tensile tests, the force of the third maximum was 565 N. The maximum relocation ε was less than 10 cm.

No significant failure occurred during the tensile tests. Long before the breaking load of the bamboo was reached, the soil partly failed. The relocation of the poles caused consolidation effects of the mud and afterwards it was possible to apply a higher load. Because of these soil characteristics, a dynamic structural design approach can be applied.

Failure of parts of the bamboo fence due to a static horizontal force is only possible if a very large force is applied constantly over a longer period (> 30 s). This is only possible if a larger floating item, e.g. a larger boat, hits the fence, but not due to wave action. Due to the low water depths in the investigation area, this scenario is very unlikely.

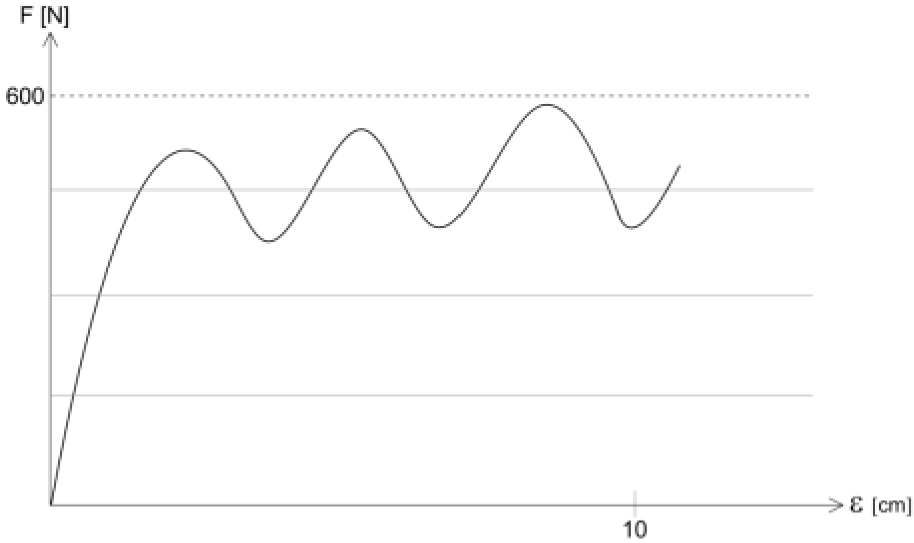

Figure 37: Results of the tensile tests

6 Monitoring

To be able to assess the effectiveness of the bamboo structures, a comprehensive monitoring programme is essential. The effect of the 10 m sample section is locally limited. However, monitoring should begin before the installation of further structures. It helps to draw conclusions about the structure itself, its wave damping effect and its effects on the surrounding sediments.

For the sample section, the monitoring should consist of:

- Visual control and photo documentation of the connections and the bundles.
- Control of the strength of embedment of the vertical poles, for example vibration by hand.
- Monthly, georeferenced photos. The camera position on the dyke was marked with a concrete foundation (cf. Figure 38). The height, the vertical angle and the direction of the camera must be documented and be the same for every photo so that the development of the area behind the sample section can be observed. The resolution of the digital camera must be high enough for an adequate zoom.
- Control of the degree of consolidation of the mud directly behind the breakwater and at another location that is not affected by the structure. Instead of a geotechnical analysis of soil samples in a laboratory, simplified, qualitative approaches can be used at this stage. For example the time that a steel ball (diameter ~ 3-5 cm) needs to sink through the mud over a defined depth (~ 30 cm) can be documented. At each position a series of 10 tests should be done. The tests should be repeated every month. In more consolidated mud the steel ball will need a longer time for the same distance.
- Pressure transducers should be used to measure the wave heights and wave periods directly in front of and behind the bamboo fence to assess the transmission coefficient in nature. This should be done during the highest tides in a month.

Figure 38: Preparation of a landmark for the monitoring

After installation of the complete fences and wave breaker,the monitoring programme must record the development of the shoreline, the floodplains and the tidal flats between the dyke and the bamboo structures. The shoreline should be defined as the line where the deep mud starts. Due to the shallow water depths there, soundings by boat are not sufficient. The bottom elevation should be measured manually with a Differential GPS in a 10 m grid. After the first measurement just before the further construction, monthly measurements should initially be carried out; after six months this interval should be reduced to quarterly measurements.

To assess the effect of the structures compared to other locations, one other location where no measures were applied must be monitored regularly parallel to the focus area. This will help to identify morphodynamic processes that are related to superposed trends.

Changes in the grain size distribution and the degree of consolidation (compactness) in the surroundings of the measurement should be analysed by means of quarterly sediment sampling and analysis in a 25 m grid.

Measurements of suspended sediment concentrations, waves and currents should be carried out within campaigns covering different seasons starting immediately after the construction and continued semi-yearly.

Aerial views – or better – orthophotos in an annual cycle are helpful to follow and quantify the morphologic development.

Based on the monitoring, the adequate time for planting mangroves on the tidal flats can be identified.

All recorded data should be analysed to provide a detailed control of success of the measures.

7 Recommendations and Lessons Learnt

Recommendations for further construction can be given based on the installation of the sample section. In this report the adapted design and the different installation methods are described.

The irregular form of the bamboo poles and local discontinuities in the soil require an adapted design of the bamboo fence. Due to the high strength of the embedment, the distance between the vertical poles could be increased. This simplifies the installation significantly and decreases the material costs.

During construction adaptations are always necessary. Therefore, the values and dimensions given in the original design have to be used with a tolerance. The degree of the tolerance is the decision of the site manager.

The construction materials were delivered as required. It was possible to get bamboo poles with the relative large diameter of 8 cm and a length of 4.70 m.

All installation methods tested worked well under the given site conditions. The method to be used for the construction will depend on the boundary conditions at the construction site (water level, depth of the mud) but also on the workers. Based on the experience from the sample construction it should be possible to install 10 to 15 m bamboo fence per day with a 4 person team.

A higher workload can be reached by using more teams or machines. The best installation procedure would be a dredger on a pontoon. Then, the bamboo poles can be pressed into the mud and sand with the dredger bucket (Figure 39). The material can be stored on the pontoon. The dredger can work along the side of the pontoon and use its dredger bucket to pull itself forward in the mud, to install the next section. After installation of the two rows of bamboo poles, workers can follow and connect the horizontal bars and install and compact the bundles. The work must be done during calm weather conditions.

Taking into consideration the difficulties of the first tender, it is recommended that the GIZ project be in charge of the site management and coordinate the different companies and workers during the further construction:

- Construction materials: Ordering, coordination of the supply and control of the bamboo poles, bundles and connection material.
- Installation of the bamboo poles: Finding a local company and describing the installation process using a pontoon and a dredger. Coordination and control during the construction works.
- Connections and bundles: Coordination of the team of locals who connect the horizontal bars and install and compact the bundles.
- Accomplishment of the measures of construction supervision.

Although the hydraulic and morphodynamic effects of the sample section are local and limited, a monitoring programme should already start before the construction of further structures. It helps to generate information about the stability of the structure itself and the connections, the wave damping effect and local morphologic changes. After the installation of further bamboo fences, the monitoring should be expanded.

Figure 39: Installation of vertical poles using a dredger bucket

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