Case study for Application of Geotextile tube in the construction of Reclamation Dyke in Eco-sensitive zone

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ABSTRACT

The Addu Development Project (ADP) was formulated to transform Addu City (south of Maldives archipelago) into a fully functional city, a thriving economic and a tourist hub apart from making an effort to decongest Male. In order to preserve and protect the natural coral & marine ecosystem, a one-off ~ 228 Ha land reclamation and shore protection project was proposed to create residential, commercial, and tourist infrastructure. Within this scope, it was proposed to undertake Dredging, Reclamation and Shore Protection Works to reclaim lagoons to form 3 artificial Islands covering ~ 25 Ha, where the private sectors would be invited to develop resorts. The project was awarded subsequently to Van-Oord, Netherlands on EPC basis.

The design water level considered as HAT + Sea level rise as 1.17m MSL and the island reclamation fill was proposed to be built up to minimum (+)1.6m MSL. In the absence of natural rock in the vicinity, the traditional rubble and concrete systems of construction of reclamation dyke was ruled out and sand filled Composite Geotextile tube technology was adopted as a system of choice. A two-tier stacked 11m circumference Geotextile Tube system with scour protection apron was designed & installed for all the lagoon resort islands.

This 3 layered Specially Engineered needle punched Composite material comprising of high tenacity composite PP woven Geotextile sandwiched between a sand-colored abrasion resistant Nonwoven textile outer layer and another Filter fabric inner layer was indigenously manufactured and fabricated to site specific designs.

The key challenges of installation of this system for Van-Oord was the dredged material compositions, availability (without disturbing the natural habitats) apart from the need to collaborated with coral specialists on the relocation of coral and associated flora and fauna prior to construction work. The additional challenge was maintaining pumping pressure due to extra long dredge lines.

Keywords: Reclamation Dyke, Dredged fill, Geotextile Tube, Artificial Island, Geo-composite

1 INTRODUCTION

The Ministry of National Planning, Housing and Infrastructure of the Republic of the Maldives had issued the tender for the Reclamation by Dredging & Shore Protection works for approximately 228 ha of land in Addu City.

This project was part of the Addu City Development Project to help transform Addu City into a fully functional city, a thriving hub and an attractive tourist destination, by enhancing connectivity, addressing climate change & environmental protection and promoting decentralization. The Ministry had invited prequalified EPC contractors to submit an offer for the following scope:

- Dredging, reclamation and shore protection works
- Storm water drainage

The project is executed in the following two sections:

- Section 1

Reclamation and shore protection for the embankment for road and other civil works at four lane link road diversion area.

• Section 2
Reclamation, shore protection and other miscellaneous works including drainage at the following locations:

- o Maradhoo - 76 ha
- o Hithadhone zone 01 and zone 02 - 90 ha
- **o Island resorts 1, 2 and 3 - 25 ha**.

Fig 1. Project location Addu City, Republic of the Maldives

2 DESIGN SOLUTION WITH GEOTEXTILE TUBES

For the construction works of Section 2 (Resort Islands), it was proposed to undertake Dredging, Reclamation and Shore Protection Works to reclaim land in lagoons to form 3 artificial Islands covering ~ 25 Ha, where the private sectors would be invited to develop resorts. The project was awarded subsequently to Van-Oord, Netherlands on EPC basis.

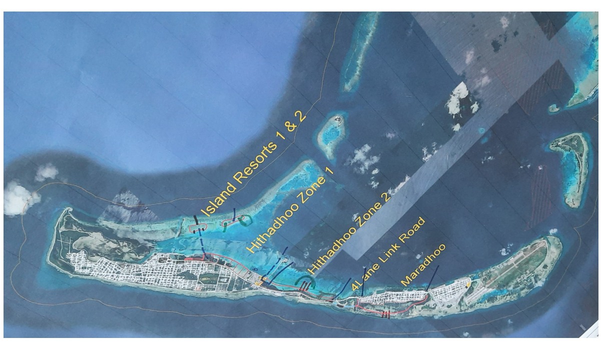

Fig 2. Proposed Island locations in Addu City lagoon

The design water level considered as HAT + Sea level rise as 1.17m MSL and the island reclamation fill was proposed to be built up to minimum (+)1.6m MSL. In the absence of natural rock in the vicinity, the traditional rubble and concrete systems of construction of reclamation dyke was ruled out and sand filled Composite Geotextile tube technology was adopted as a system of choice.

A two-tier stacked 11m circumference Geotextile Tube system with scour protection apron was designed & installed for all the lagoon resort islands.

The cross section consists of sand filled composite geotextile tubes with a crest level of MSL +1.60m.

In front of the tubes is a scour apron which is being held in place by anchor tubes. For this design, a composite geotextile GEOFIL GT650 with a tensile strength of 80 kN/, CBR Puncture Strength (as per ISO 12236) of 8.6 KN and a Drop Cone (ISO 13433) of 3 mm was used.

This 3 layered Specially Engineered needle punched Composite material comprising of high tenacity composite PP woven Geotextile sandwiched between a sand-colored abrasion resistant Nonwoven textile outer layer and another Filter fabric inner layer was indigenously manufactured and fabricated to site specific designs.

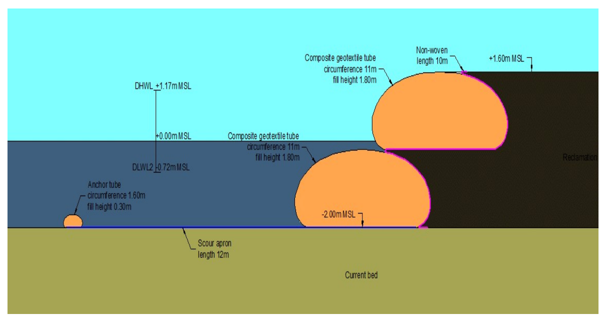

Fig 3. Cross-sectional design sketch of geotextile tubes for Resort Islands

The cross-sectional design consists of two stacked composite geotextile tubes. Both tubes have a circumference of 11 m.

Building this structure being a multi-step process, each step involved checking for governing failure mechanisms.

Below are the different construction steps, their failure mechanisms and where in this section these mechanisms are checked.

Table 1. Sizes of margins

Configuration type	Circumference bottom tube [m]	Circumference top tube [m]
Tube configuration	11	11

The sketches of the steps serve merely a visual purpose, as to clarify the conditions of the specific step, and are therefore devoid of any measurements.

Scenario 1 – scour apron – bottom tube – non-woven

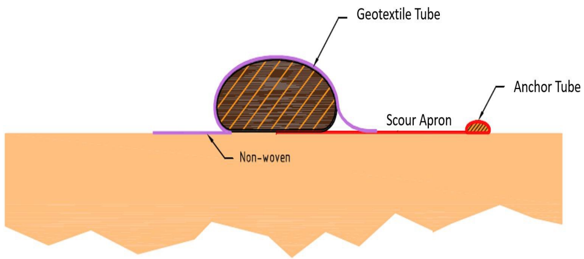

Fig 4. scour apron – bottom tube – non-woven

Table 2. Failure mechanisms scenario 1

Element	Check
Geotextile tube – bottom	Tensile strength
Geotextile tube – top	Tensile strength
Geotextile tubes	Stability in waves
Geotextile tube – top	Overturning
Geotextile tube – top	Horizontal sliding

Scenario 2 – backfill bottom

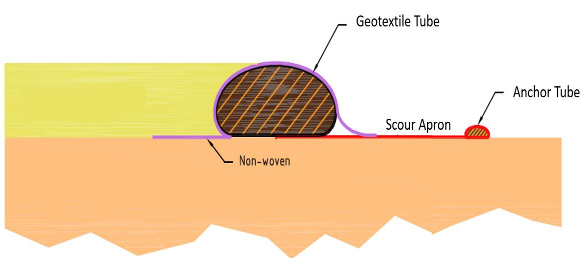

Fig 5. scour apron – bottom tube – non-woven

Table 3. Failure mechanisms scenario 2

Element	Check
Geotextile tube – bottom	Horizontal sliding
Geotextile tube – bottom	Overturning

Scenario 3 – tube top - backfill top

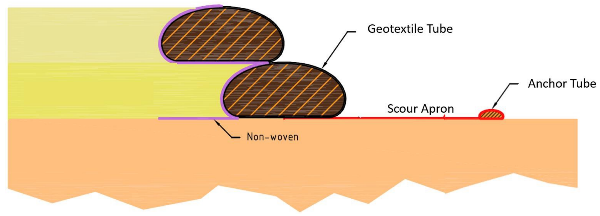

Fig 6. scour apron

Table 4. Failure mechanisms scenario 3

Element	Check
Scour Apron	Length
Scour Apron	Buoyancy anchor tube
Geotextile tube – bottom	Tensile strength
Geotextile tube – bottom	Stability in waves
Geotextile – general	Erosion of fill material

INSTALLATION

The works started with levelling and cleaning of the area where the geotextile tubes were to be installed. It is important that sharp and pointy objects are removed from the seabed. Peaks and depressions will be equalised to generate a more uniform surface on which the geotextile tubes will rest. Backfilling was not be allowed at location where geotubes were to be placed .

Several temporary installation platforms and installation frames were prepared and positioned where required for the installation of the geotubes and scour aprons.

A pedestal excavator Hitachi ZX470 was proposed to be used to level and clean the sea bed areas. The excavator in this configuration can drive over the seabed in the water to a depth of 1.50m.

3.1 INSTALLATION OF LOWER GEOTEXTILE TUBES

After the seabed has been levelled and all sharp obstacles have been removed, the lower geotextile tubes can be installed. Using the positioning system of the pedestal excavator, big-bags will be positioned next to the designed alignment of the geo-tube. These big-bags will be used as an anchor during the installation of the tube. Figure-8

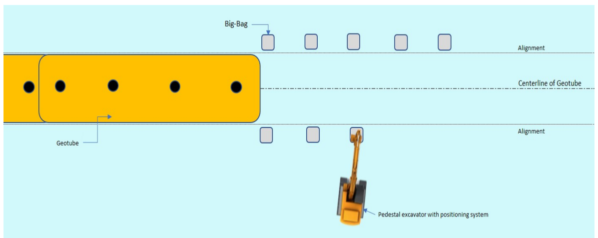

Fig 7. Installing big-bags next to alignment of next geo-tube

After the anchors (big-bags) are in position the pedestal excavator picks up the frame with a new roll of geotube and brings it in position at the end of the last placed and filled geotube. The end of the geotube is unrolled and placed on top of the previous geotube with 3 meters overlap. The end of the tube is tied up to the previous one and slowly unrolled by the excavator. The pedestal excavator operator can see the exact position of the to be installed geotube on the survey positioning system installed in the excavator, so he will follow the footprint when unrolling.

A team of workers will assist and connect the geotube to the anchors (big-bags) to keep it in the required position during unrolling and filling.

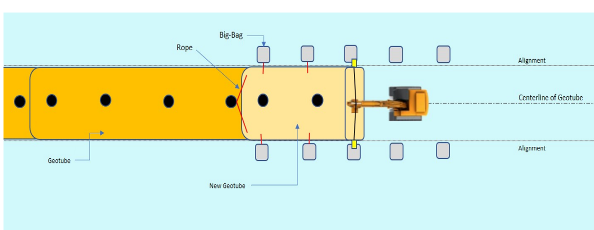

Fig 8. Installing new geotube to anchors during installation

Fig 9. Pedestal excavator installing new geotube

Fig 10. Workers assisting during installation

Once all connected ropes and the actual position of the tube is check, the geotube can be filled with sand

The typical site conditions encountered here were -

- Low Wave Height due to presence of coral reef on the East & North of the Island 1 &2
- The Southern end was marginally vulnerable from wave action – sheer by location (Apron installation was made mandatory here)
- The Bed material mostly comprised of crusty coral sand and the loose sand movement was much lower than open sea shore.

3.2 FILLING THE GEOTEXTILE TUBES

A second pedestal excavator was brought within the boundary of the resort island. This excavator was equipped with a dredge DOP pump with a capacity of 300 to 600m3/hr. The DOP pump is driven by hydraulics from the excavator.

A high pressure water jet pump is needed to loosen the material from the seabed consisting of coarse sand. This pump is placed at the back of the counter weight of the excavator by means of a steel support frame. Capacity of the water jet pump is 80m3/hr and the pump can be operated with remote control by the excavator operator.

Fig 11. Pedestal excavator equipped with DOP and water jet pumps

From the DOP pump the mixture of water and sand will be pumped through a floating pipeline which is connected to one of the filling points of the geotube. The floating pipeline will be positioned by the other pedestal excavator. Once sufficient material is pumped on this filling point, the pumping of material will be stopped and the floating pipeline will be connected to the next point. This will be repeated till the complete geotube is filled. The pressure of this DOP pump is not high, so that the dredged material is not injected into the geo-tubes under high pressure.

A supervisor was present at all times during the filling process so that the geotextile tube is filled according to the correct controlled method. The excavator operator will operate both pumps and gain experience of what the best mixture will be to be pumped through the floating pipeline.

At first the filling ports at the far end of the geotextile tube are used, while those in between remain closed. One end will be used for the sand-water mixture and the opposite end for water relief and discharge.,

Fig 12. Supervision during installation

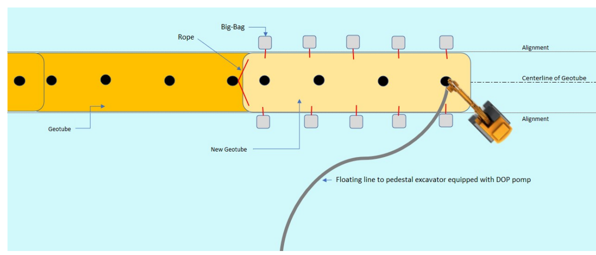

Fig 13. Filling geotube

In this way the sand slurry will flow from one end to the other of the geotextile tube and depositing sand along its way.

Local sand was used and properties varied in different locations. When a sand-water mixture is pumped into the geotextile tube the sand will settle and the water typically flows out through the pores of the geotextile.

The sedimentation rate determines how long it will take for the sand to settle. Should the pores of the geo tube become clogged so that the mixture does not flow well sideways, the sand water mixture can be agitated by using wooden rammers on top of the tubes. The density of the mixture can be determined by taking samples and then measuring weight and volume. Sand mixtures generally have densities between 1,300 and 1,400 kg/m3. The geo-tubes are designed with a safety of 1,900kg/m3.

The Flow Rate (ISO 11058) through the fabric also had a +ve tolerance (17.5 l/m2/s as against Design value of 14 l/m2/s) which converts to quick release of water pressure through the fabric.

Fig 14. Pedestal excavator with floating pipeline

Fig 15. Pedestal excavator filling geotube

3.3 CONNECTING GEOTEXTILE TUBES

Based on the efficiency of installing the geotextile tubes around the three resort islands, the design will be based on geotextile tubes with a maximum length of 30m. The overlap between the geo-tubes will be 3.0m.

The tubes will have multiple filling points as described in the clients requirements. Not all of these filling ports have to be used at the same time, but it is advised to use all of them in the course of filling the tubes.

After a geotextile tube has been completely filled with sand, the installation of the next tube can be started.

The following process is carried out to ensure a good connection of the tube to be placed and previously installed tube.

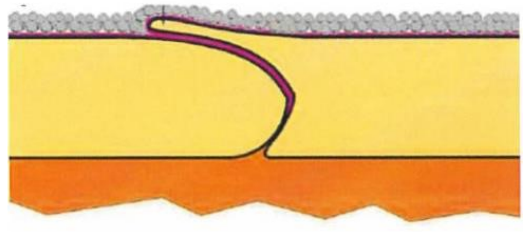

Fig 16. Connection of geotextile tubes

The next tube is partially placed on top of the previous tube with an approximate overlap of 3,0m. Filling process shall commence midway, which will allow the tube to become heavier and “anchored” to the seabed.

Once the tube has become sufficiently heavy, the valve of a supply hose to the first inlet port is opened.

The sand-water mixture will then gradually move against the previously installed tube, so that a good and tight connection will be created.

The filling process continues until the entire tube is filled uniformly. After the geo-tubes have been completely filled with sand, the inlet sleeves are tied with nylon ropes.

3.4 PLACEMENT OF SCOUR APRON AND ANCHOR TUBE

The installation of the geotextile tubes a scour apron together with an anchor tube shall be installed on the seabed. The installation of this apron is scheduled to be installed after the reclamation works has been done. But if times allows, this also can be done before.

Also before placing the scour apron with the anchor tube, it is extremely important that the seabed is levelled and that all sharp objects are removed.

The anchor tube will already be sewn to the scour apron during manufacture.

The scour apron with the anchor tube has a width of 12m and a length of 30m, while the scour apron

has overlaps of 3.0m with preceding and succeeding aprons.

The geotextile is rolled over a pipe of a “wheel” frame with truck tires on either side. This wheel frame is lifted with the excavator and can be pulled horizontally over the bottom, so that the geotextile unrolls itself.

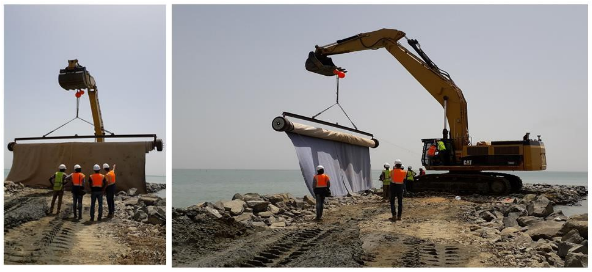

Fig 17. Installation of geotextile with a 12m long “wheel frame”

The anchor tube with a circumference of 1.60m will be filled with sand while the scour apron is kept on the sea bed

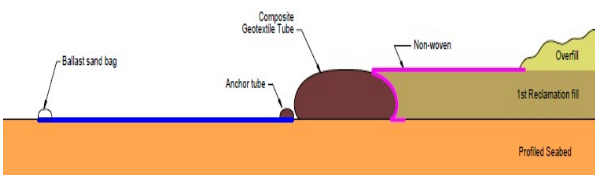

Fig 18. Typical cross-section of scour apron with anchor tube

3.5 RECLAMATION FILL

Before the TSHD HAM 318 can be mobilized, all locations for the reclamation fill must be completely ready to avoid delays and waiting times of the TSHD.
This also applies to the installation of the lower geotextile tubes with a circumference of 11m around all
resort islands.

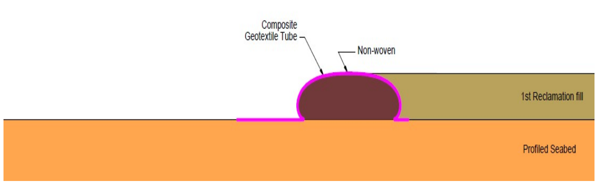

Fig 19. A non-woven geotextile cloth should be laid before the resort island is filled with sand

Before the reclamation works can be started, a non-woven geotextile cloth will have to be placed behind the lower tubes, which has to be folded back later to install the upper tube.

The function of this geotextile is to guarantee a complete seal for the sand between the upper and lower
tubes.

The approximate perimeters of the three resort islands are the following:

- Island 01: 1,210m
- Island 02: 1,474m
- Island 03: 1,453m

The work method of dredging and reclamation will be described in another document.

An excess of dredged sand will be applied to the three resort islands so that the TSHD will not have to come back after the upper geotextile tubes have been filled with sand.

The Island Resorts do not include any rock revetment and are merely constructed using composite geotextile tubes and scour apron.

Installing sandy beaches around the islands is not within the scope of the contractor.

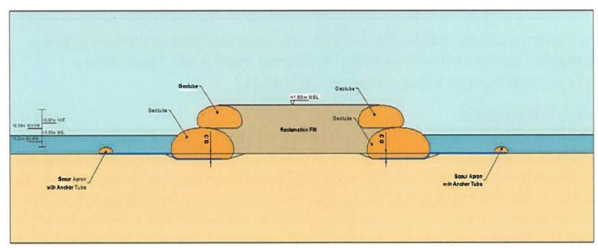

Fig 20. Typical cross-section of Island Resorts A non-woven geotextile cloth should be laid before the resort island is filled with sand

3.6 PLACEMENT OF UPPER GEOTEXTILE TUBES

After the fill for the reclamation has been completed, the preparations for installing the upper geotextile
tubes can be started.

With a wheelloader and an excavator the route of the upper tubes is cleared. Since the filling of the upper tubes will be carried out completely on dry land, a pedestal excavator is no longer needed to roll
out the tubes.

A wheelloader will be deployed to roll out the geotextile tubes with lengths of 50 m.

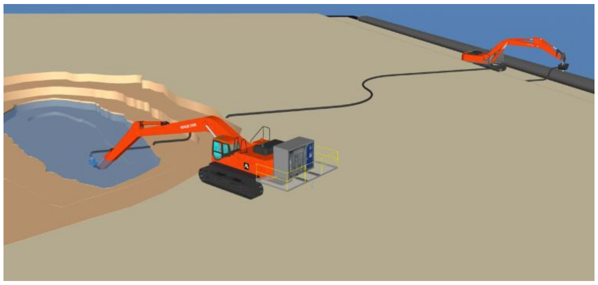

Fig 20. Filling the upper tubes with two excavators, where a temporary pit is dug in the island

Both pedestal excavators are no longer needed to fill the upper tubes with sand. Two standard excavators are used to fill the upper tubes. The first excavator is equipped with DOP and water jet pump, while the second excavator has a bucket to hold a flexible outlet pipe during filling.

In order to be able to dredge sand, a reasonable pit must be dug in the island resort in which sufficient seawater must be present to pump the sand-water mixture through the pipeline.

Extra sand was applied during the reclamation works in order to fill these pits again later.

Non-woven geotextile cloth is placed behind the lower and upper tubes so that the joint is completely closed for sand transport.

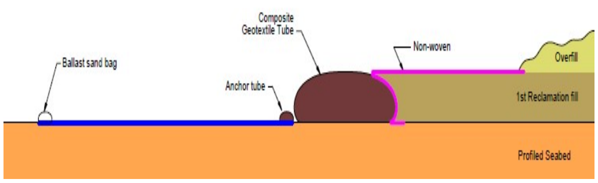

Fig 21. Before placement of second layer geo tube a non-woven geotextile should be placed

As soon as a number of upper tubes are completely filled, a start will be made with the backfill behind the upper tube. The already installed non-woven geotextile will be placed against the second layer geotube.

A D6 dozer pushes the sand into space behind the upper tubes, where an excavator carefully moves the sand against the geotextile of the tube.

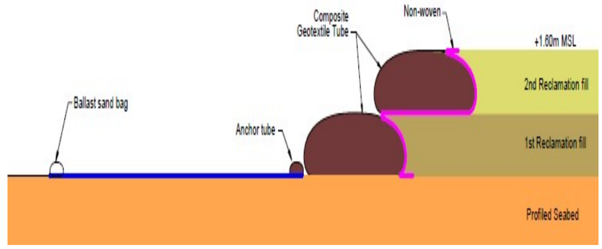

Fig 22. Non-woven geotextile to be placed against second layer geotube

4 CONCLUSION

The complete reclamation work could be completed well within designed timelines owing to the technology adopted which required negligible importation of fill material and the fragile ecosystem surrounding the islands did not suffer any negative impact.

Substantial amount of moss growth on the tubes was observed during the installation process within days – which would have a positive impact on the life expectancy of the Geotextile.

ACKNOWLEDGEMENTS (10.5pt uppercase, bold) (12 pt spacing above and 6 pt spacing below)

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Fig 23. Site Photo

REFERENCES (10.5pt uppercase, bold) (12 pt spacing above and 6 pt spacing below)

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