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# Case Studies and Lessons Learnt from Applications of Sand Filled Geotextile Containers in the Arabian Gulf

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**Abstract**: Sand filled containers (SFC) or Geotextile Sand Containers (GSC) have been used for over 40 years in the coastal zone and are increasingly being designed and implemented worldwide as cost effective, eco-friendly and sustainable coastal protection system. Some examples of SFC-structures for coastal applications are: seawalls, revetments, submerged-reefs, groins, dune-reinforcement, breakwaters, and scour-protection-systems.

SFCs require specialist design and construction methods but have a large number of intrinsic advantages including safety, providing a good substrate for marine growth, speed of construction and cost, particularly in areas, such as the Arabian Gulf, where good quality rock is rare. Recently developed stability tools can check that that the SFC meets stability requirements. Construction needs to be considered in the design phase as it requires different equipment and techniques to rock and poor construction methods at a few sites worldwide have lead to excessive costs and failures.

SFC projects in the Arabian Gulf and Tanzania have been are reviewed with respect to design, construction and monitoring of SFC in developing areas. The results offer important and transferable lessons regarding covering feasibility, design aspects, construction methods and post construction issues.

***Keywords****: sand filled containers; geotextile; design; construction; monitoring; maintenance.*

## INTRODUCTION

Permanent and temporary emergency coastal protection and improvement works are increasingly being designed and implemented worldwide using Sand Filled Containers (SFC) or Geotextile Sand Containers (GSC). Some examples of SFC-structures for coastal applications are: seawalls, revetments, submerged-reefs, groins, dune-reinforcement, breakwaters, and scour-protection-systems. In principle, any type of coastal structure normally constructed of rocks or other hard material such as concrete can also be built with suitable sand filled containers. SFC can range from several hundred Kg to hundreds of tonnes and they are increasingly popular as they can provide a good solution to a wide range of problems with intrinsic advantages but achieving these advantages requires appropriate design, construction, monitoring and maintenance (Jackson 2010).

## CASE STUDIES

SFC projects involving seawalls, breakwaters and groynes in two remote island locations in the Arabian Gulf and one beach resort hotel in Tanzania have been are reviewed with respect to design, construction and monitoring of SFC in developing areas. These case studies add important and transferable lessons regarding feasibility, design aspects, construction methods and post construction issues in developing areas with an emphasis on the following:

a. Design issues
b. Environmental considerations
c. Construction methods
d. Maintenance

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**Figure 1:** Sand Filled Containers at 3 sites
**Top Left:** SFC groyne under construction (UAE). **Top Right:** 5t SFC wall under construction (Tanzania).
**Bottom:** Low crested SFC breakwater after installation (UAE).

**DESIGN**

SFC structure design is a specialised area and there is presently no "Sand Filled Container Design Manual". However, considerable research has been undertaken (Pilarczyk, 2000) and the following inter-related issues need to be considered in the design of SFC structures:

- Use of structure:
    - recreational use on and close to the structure?
    - low crested?
    - Possibility of vandalism?

- Design life
- Staging
- Accessibility
- Will the structure be able to be monitored and maintained?
- Environmental issues
- Site conditions:
    - Waves
    - Tide heights
    - Bathymetry
    - Currents
    - Sea bed characteristics
    - Scour potential
- Construction methodology and equipment available – fill smaller containers and then place or fill larger containers in situ
- Fill material characteristics
    - % fines
    - Rubble – size and shape
- Type of geotextile
    - woven
    - non-woven
    - woven / non–woven composite
- Geotextile properties, particularly:
    - Strength
    - Puncture resistance
    - Durability
    - UV resistance

SFC behave very differently to rock and considerable work has been done to understand the behavior and stability of SFC individual units and structures (Recio and Oumeraci 2009). SFC are often used when low crested structures [LCS] are preferred as the high unit weight is stable with overtopping. Design of LCS requires modelling that allows for wave transmission. Flume modelling by numerous researchers has provided good empirical tools for predicting transmission coefficients for use in numerical models. Recent developed models can be used to model wave-structure interaction for assessing, turbulence, scour and stability. Figure 2 shows an example. Individual and stacked SFC are flexible and accommodate settlement and scour.

The shape of filled containers depends on the fill characteristics, % full, water depth, filling pressure, etc but can be predicted accurately. As SFC are modular, they lend themselves to temporary works, flexible design and staged / stepped design. For example, with a “flexible design” approach, crest heights can easily be raised and / or structures lengthened or shortened after monitoring.

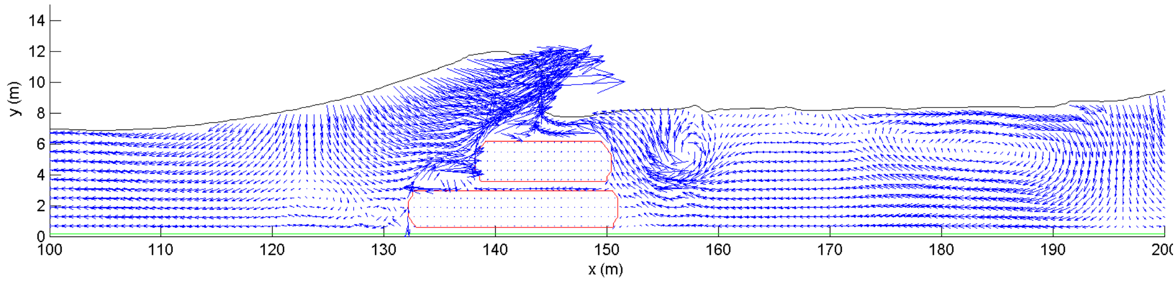


**Figure 2: Wave Modeling for Assessing Wave-Structure Interaction and Stability of a low crested SFC Structure**

## CONSTRUCTION

Construction of SFC structures requires a very different methodology to construction of conventional structures. The following inter-related issues need to be considered in the development of a construction methodology for SFC structures:

- Size of containers
- Access
- Equipment available
- Environmental constraints
- Supervision, divers and labor available
- Site conditions during construction period:
  - Waves
  - Tide heights
  - Currents
  - Sea bed characteristics – if rock, need
- Equipment available – fill and place smaller containers or fill larger containers in situ
- Fill material characteristics
  - % fines
  - Rubble – size and shape (need to sieve to remove?)
- Anchorage of containers filled in-situ to obtain accurate placement.
  - concrete weights
  - Anchors
  - frames
- Diver availability and safety

For SFC, designing with constructability in mind is very important.

## MONITORING AND MAINTENANCE

All coastal structures should be monitored and maintained. Patching methods for above and below water have been developed and maintenance (or replacement) of SFC is simple but important to do before the fill is lost.

**LESSONS**

The use of SFC is suited to a wide range of applications, but particularly when:

- Low crested structures are preferred.
- There is a high usage at the site for recreation.
- Temporary, flexible or staged design is desired to allow speedy implementation.
- Rock is scarce and / expensive and there is suitable sand for filling at or near the site.
- The site has difficult access for large equipment and trucks.
- Vandalism and impact loads from vessels or large debris is not a serious threat.
- The look of SFC is not an issue (SFC are not loved by all!).
- Environmental: if a small foot print is required or creation of habitat is desired.
- Suitable design tools and simple hands-on construction methods have proven the most suitable.
- An integrated design and construction approach is preferable.

Specific lessons:

- **Design issues**:
    - Each project should be investigated individually; an optimal SFC solution for a specific site may not be applicable to other location with different conditions such as wave climate, nearshore slope, tides, sediment transport rates, and/or geotechnical conditions.
    - Recent developed design tools - formulae and numerical models (Recio and Oumeraci 2009) - should be used to ensure that all relevant parameter are considered during the design process.
    - Due to the modular nature of the containers and the relatively easy and low cost mobilization, projects can be easily designed to be constructed in stages or modified, if conditions or requirements change.
    - SFC structures can have high unit weights that make them resistant against wave action and coastal related natural hazards.
    - SFC structures are “soft” and hydraulically smooth making them safer for users and ideal for low crested applications.
    - SFCs are flexible and can adapt and conform readily to changing site conditions and morphological foundation changes.
    - SFC structures are flexible and smooth behaving advantageously under cyclic hydrodynamic loads.
    - SFC can be easily removed, if the need is mitigated or other solutions are implemented.
    - SFC modules can be easily replaced if damaged or the whole structure covered in rock, if a longer life cycle is required.
- **Construction**:
    - Filling and placing SFC are critical to the stability and performance of the SFC structures.
    - Suitable filling equipment, sand granulometry, filling ratio/speed, SFC anchoring should be carefully assessed.

- Smaller construction equipment requires less mobilization time and costs.
- Unskilled labour can be used if methodology is simple.
- If efficient local dredgers are not available or the fill has significant rubble, use of filling hoppers with vibrating screens is a simple alternative.
- Diving tasks need to be minimized and simple to avoid loss of time:
  - Prefabricate anchors
  - Use simple rope grids for setout – avoid complex systems.
  - Safety management plans and good supervision are essential.
- Importation of rocks by barge and / or trucks can be eliminated.
  - local sand can be used for filling.
  - where rock reserves are limited, this resource can be preserved.
  - the need for trucks to travel through highly populated coastal areas is not required.
- Inspection and maintenance plans should be implemented after construction.

- **Environmental**:
  - SFC structures are usually covered with marine or coastal flora, giving the structure a low visual impact and "natural" appearance as well as providing significant environmental benefits.
- **Cost**: Lower total construction and life cycle costs due to:
  - smaller volume
  - smaller non-sophisticated equipment requirement
  - low-skilled labour requirement
  - use of locally available sand.

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