CHAPTER 92

SOME EXPERIMENTS WITH SAND-FILLED FLEXIBLE TUBES

by

Per Roed Jakobsen, M sc , Danish Board of Maritime Works

and

Arne Hasle Nielsen, M Sc , Danish Institute of Applied Hydraulics

ABSTRACT

Experiments with the use of long sand-filled flexible plastic tubes ("Sand sausages") have been carried out for coastal protection purposes at several exposed locations along the Danish coasts since 1967 In general the results have been encouraging

Several methods have been used to fill the tubes with sand A simple inexpensive hydraulic method for easy filling of almost impermeable tubes on site has been developed by model and prototype experiments with promising results

As a result of the experiments it seems likely that sand-filled tubes may be used with advantage as temporary structures, i e for full-scale pilot investigations and to solve acute problems, or they may be incorporated in more permanent structures

1 INTRODUCTION

Flexible sand bags have been used in hydraulic engineering practice for many years, but due to the poor quality of available materials the use was mainly restricted until recent times to projects of non-permanent nature such as emergency flood control and protection of dikes

However, with the development of fabrics of durable, strong synthetic fibres of nylon, polypropylene, etc , new possibilities have arisen for more permanent use of large sand bags in more exposed locations than could previously be considered

The paper describes some preliminary experiments with long flexible sand tubes in coastal protection works that have been carried out in Denmark since 1967 by model and prototype experiments

2 FILLING METHODS

One of the major problems in the economical use of long flexible sand tubes is filling the skin

Several ingenious devices and filling methods have been developed for the filling of skins of permeable fabrics The sand is usually transported into the tube by hydraulic pumping and the water escapes through the permeable fabric, leaving the sand grains in the tube

In most cases the discharge tube is drawn backwards inside the tube with a speed corresponding to the rate of filling leaving the filled tube behind (Fig 1)

A much simpler and more economical hydraulic filling method which allows filling of sand tubes to almost any length above or below the water surface from the "front" end of the tube has been developed simply by using impermeable instead of permeable fabrics

When the mixture of sand and water flows into the impermeable flexible tube, the sand settles out near the inlet until the cross-section has decreased so much that a small "river" is formed in the tube on top of the accreted material

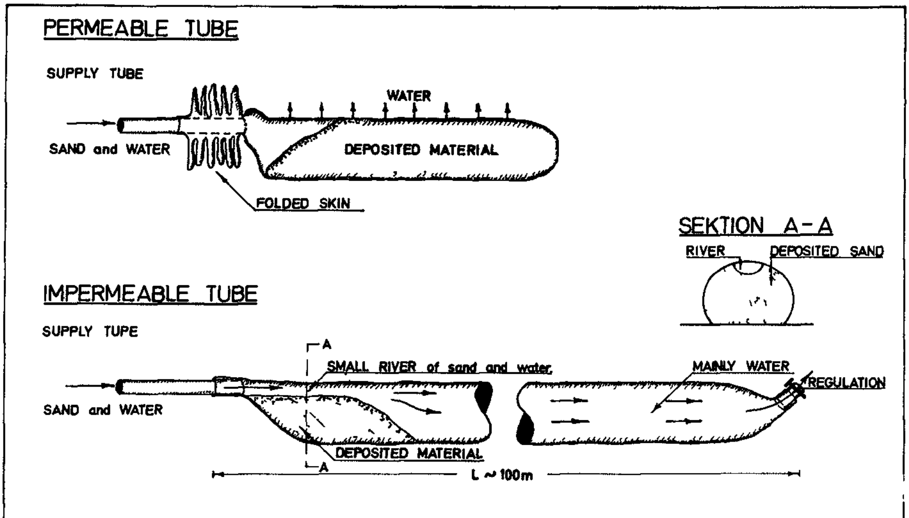

FIG 1 PRINCIPLES OF FILLING OF FLEXIBLE TUBES

The mixture of water and sand is now transported foreward in the tube and the sand grains settle out in front of the already accreted material, while the water leaves the tube through an opening at the far end By decreasing the outlet opening, the skin may be expanded by water pressure whereby an almost circular, filled cross-section can be obtained

In laboratory tests the sand/water mixture was injected by sand-pumping, while in experiments in the field a different method was primarily employed water was fed under high pressure through a type of diffusor into which the filling material was added directly

The impression has been procured from the experiments that in principle almost infinitely long, large cross-section tubes can be filled by hydraulic pumping provided the skin is impermeable at the time of filling

3 EXPERIMENTS IN NATURE

While the filling method was developed by model experiments the resistance of fabrics to atmospheric conditions, ultraviolet sun rays, ice, human activity, etc , was investigated by full scale experiment in nature where various types of constructions were also tested under different conditions

Experiments were conducted in about 10 different locations, including sites on the exposed coasts of Jutland and on the more sheltered island coasts of Funen and Zealand

The type of structures employed in natural locations so far has in most cases been groins, in some cases however revements and embankments have been built

Cross-sections of the various structures have been (1) a single tube, (2) one tube resting on two tubes, forming a triangular cross-section, and (3) two tubes placed at the sides of an interjacent sheet covering a sand-prism. Future plans call for experiments with multicellular cross-sections.

Tubes of a diameter of up to 100 cm have been filled to lengths of up to 100 meters, and at water depths of up to 3 meters.

Various methods have been tried to make the rubes in the structures behave as units. In some cases tubes have been lashed together by plastic ropes, in other cases tubes have been wrapped in filter sheets. Later experiments have involved weaving together the lower tubes in prism structures.

Fig. 2. Structures composed of sand tubes with diameter 0.7 m (1 tube on top of 2)

In almost all the structures installed on sandy beaches there has been a problem of bottom protection. (The authors are aware that in autumn 1970 sand-tube structures with a new form of bottom protection of filter sheeting have been erected on the coast of South Carolina, U.S.A.).

On shingle beaches there have been no problems of bottom protection.

In all the experiments tubes have been entirely unprotected; in less exposed locations such structures may have a working life of several years. For permanent use of tubes above the water surface, tubes should be protected by a covering layer of rocks or similar material.

The first sand-tube experiments conducted in Denmark took place in spring 1967. The only point worthy of mention in this connection is that one of the filled tubes, laid at a depth of water of approx. 100 cm and

Fig. 3. Tubes wrapped into a filter sheet.

thus protected against sunlight, is still intact, covered with barnacles, cockles and other sea-life.

Some of the experiments are illustrated and described below.

Fig 4 shows the small fishing town of Lønstrup on the west coast of Jutland. Tidal range is about 0.3 m but wind set-up may be about 1.5 m combined with heavy wave action.

The littoral South-North drift is estimated at approx. 500,000 m^3 p.a. On account of the poor condition of the existing high wooden groin, which was no longer able to ensure the necessary build-up of the beach, three sand tubes were laid out in 1967 along the foot of the groin. As anticipated, this caused a considerable build-up of the foreshore.

The tubes sank somewhat during the winter of 1967-68 although they had been given bottom protection in the form of filter sheeting - but they stopped sinking when they came to rest on an old stone layer, the remains of the foot protection of the wooden groin. Consequently another three tubes were added in 1968.

In autumn 1969 the structure was severely damaged during a military landing exercise.

The structure was repaired in 1970 as shown in the illustration, with a prism groin comprising three hydraulic filled tubes, diameter 0.7 m, lashed together with plastic ropes, the lower tubes woven together.

In spring 1969 an experiment began on the barrier beach south of the harbour at Hvide Sande on the west coast of Jutland (See Fig. 5). The experiment served three main purposes:

1. A further development of sand tube constructions.

Fig. 4. Sand tube groin (Lønstrup at the Danish North Sea Coast).

2. To obtain better knowledge of the applicability of sand tubes in coastal protection works.
3. Measures against a downdrift recession caused by a mole built to protect the Hvide Sande inlet.

The barrier is only about 1 km wide but has a natural protection of dunes.

The coast is exposed towards the west, prevailing winds from W-NW, and the N-S littoral drift is estimated at 400,000 m^3 p.a. Tidal range less than 0.8 m, wind set up may be up to + 3.0 m.

The constructions described in the following were with few exceptions made of three tubes laid out to form a prism. The tubes were permeable made of double layers of black polypropylene monofilament.

Group 1: Four beach groins. (Fig. 5).
35 m long, starting on the dune at a level of + 6-7 m, ending on the beach at level + 2 m.

Group 2: Two artificial beach ridges.
One half-moon shaped with a shingle drain under the middle section. Total length 70 m.
Laid out with top level - 0.2 m at the front and the ends at top level appr. + 1.0 m.
The construction never really worked because the permeable tubes over the drain were washed out by a gale during the construction period.

Fig. 5. Beach groins (Hvide Sande. The danish North Sea Coast).

The other ridge boomerang shaped.
Total length 70 m. Laid out on the beach at level + 1 m. After a short while the structure sank and is now buried in the sand.

Group 3: Two groins going from the dune foot to the still water line, spaced 120 m apart and at an angle of 20° north to the coast normal.

Group 4: As group three, now showing 20° south.

Finally two constructions in the form of dozed sand prisms normal and parallel to the coast covered with a filter sheet stitched on both sides to individual tubes; unfortunately the stitching was not strong enough and the structures failed after a short while.

Experimences:

The material has shown good resistance to the forces acting upon it. The tube structures must be held together by some means: It is essential to pay careful attention to the problem of bottom protection. Some attemps were tried with filter sheet but were not properly executed. Thus the "groins" and "ridges" followed the seasonal beach fluctuations down - but of course never up again.

A extensive measurement program following the experiments will be finished and finally evaluated in the summer of 1971 so far it can be stated that in the period summer 1969 to spring 1970 stabilisation of the beach has been noted.

Fig. 6. Enebærodde (Funen).

On the Enebærodde spit on the north coast of Funen a contractor has been conducting some experiments, that began in autumn 1969.

There was a minor erosion problem in the test field.

The tubes used were made of polypropylene lined with plastic D = 0.70 m.

There have been some interesting features in these experiments especially concerning some groins made of single tubes going to a water depth of approx. - 1.0 m. (Fig. 6).

1. The sand-tube groins in this relatively calm area had a significant traditional groin effect.
2. The groins did not show any damages in the breaker zone.
3. During the severe winter 1969-70 the tubes remained intact, although subjects to rather hard ice attacks.
4. The spit consists mainly of rather coarse material (shingle) but this has not apparently caused extra wear on the tubes,
5. but keeps them from sinking.

Lately - spring 1970 - sand tubes have been used for dune foot protection on an artificial spit along the Lime Inlet on the west coast of Denmark.

Fig. 7. Sydhalen (Thyborøn).

The tubes were laid out on the west beach of the spit and thus face the east part of the southern Thyborøn barrier; the construction is not therefore in a very exposed position. (Fig. 7).

The structure is a 2 x 100 m prism arrangement with three 70 cm diameter tubes made of polypropylene tubes limed with impermeable plastic foil.

On the southern section the tubes are lashed together with ropes while on the northern section the two lower tubes are woven together. Later sand will be dozed up between the eroded dune and the structure.

The tubes were filled very succesfully by the hydraulic principle and had a very high filling degree, a level of about 90 % of the theoretical diameter being obtained.

In June 1970 the first 1 m diameter tube was laid out north of the harbour at the Skaw.

The effective height obtained was approx. 90 cm, the far end of the tube was positioned at a water depth of approx. 3.0 m.

It was build in an old landing stage, and accreted in a short while sand to a height varying from 0.20 cm at depth 1.50 cm to 1 m at the shore end.

Other projects have been carried out, and new are under preparation.

4 MATERIALS

Several types of polypropylene fabrics have been used for the skin of the tubes

White polypropylene very soon appeared to have an unsatisfactory resistance to the influence of ultraviolet sun rays, and the fibres of a black polypropylene monofilament had an unfortunate tendency to slide so the sand grains could be washed out

A woven black fabric, multiplex polypropylene splitfibre, seems to have solved most of these problems and has furthermore proved very resistant to icy conditions and to the effect of human activity, at bathing beaches for more than 1 year When the hydraulic filling method is used the skin is lined with an inner tube of plastic foil to obtain impermeability

Tubes with diameters of up to 1 0 m have been filled to lengths of up to 100 m and at water depts of up to - 3 m The filling material has been natural beach sand with mean grain diameters of about 0 25-0 50 mm A recent small test with hydraulic filling of a tube with a mixture of 1 part cement to 3 parts of sand has worked out well

CONCLUSIONS

On the basis of preliminary experiments conducted hitherto the following conclusions may be drawn

(1) Impermeable sand tubes can be filled above and under the water to almost any length by hydraulic pumping
(2) The selected type of fabric has demonstrated relatively good resistance to the forces acting in coastal environment
(3) The experiments have shown that sand tubes may be used with advantage to solve minor coast problems, as temporary structures and for prototype pilot tests because the sand tubes can be easily removed
(4) If sand tubes are protected from sunlight and from human activity their use may be of a permanent nature
(5) Many problems are still unsolved and the use of tubes is still in the development stage Work is in progress towards development of larger and more economical sizes of tubes