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Coastal erosion prevention by geotextile tube technology

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Abstract

Recently, geotextile tube technology has changed from being an alternative construction technique and, in fact, has advanced to become the prime solution of choice. This paper presents the various issues related to the geotextile tube technology and case history of shore protection at Young-Jin beach on the east coast of Korea. A stability analysis by the two-dimensional limit equilibrium theory is highlighted and the hydraulic model test results are described. Based on the results of stability analysis and hydraulic model tests, a double-lined geotextile tube installed with zero-water depth above crest was found to be the most stable and effective for wave absorption than other design plans. Also, the shoreline at Young-Jin beach was extended by about 2.4–7.6 m seaward, and seabed sand was gradually accumulated around areas covered by the geotextile tube.

Keywords: Geotextile tube; Shore protection; Hydrodynamic stability; Hydraulic model test; Wave absorption

1. Introduction

In recent years, traditional forms of river and coastal structures have become very expensive to build and maintain, because of the shortage of natural rock. As a consequence, the materials used in hydraulic and coastal structures are changing from traditional rubble and concrete systems to cheaper materials and systems such as gabion, slags, geosynthetics, and so on. Moreover, shorelines are being continually eroded by the wave action of the sea, and the river and coastal structures are frequently damaged by both anthropogenic and natural causes such as overwash and storm. Geosynthetics are being increasingly used in civil and environmental applications. One of these applications is the use of geotextile tube technology. Geotextile tubes, hydraulically or mechanically filled with dredged materials, have been variously applied in hydraulic and coastal engineering fields.

The geotextile tube technology is mainly used for flood and water control, but they are also used to prevent beach erosion, and for shore protection and environmental applications (Koerner and Koerner, 2006; Muthukumaran and Ilamparuthi, 2006). Woven, non-woven, and composite synthetic fabrics, i.e. geotextiles, have been used for the past 30 years for various types of containers, such as small hand-filled sandbags, three-dimensional fabric forms for concrete paste, large soil, and aggregate-filled geotextile gabion, prefabricated hydraulically filled containers, and other innovative systems involving containment of soils using geotextiles. Koerner and Welsh (1980) and Pilarczyk (1990, 1995) provide an overview of the many primarily erosion-control applications using the various types of containers. Heibaum (2002) also presented various case histories of geosynthetic containers applied as armour, ballast, filter, storage, core for hydraulic structures, flood protection, scour repair and protection, and improvement of earth dam. Sprague (1995) presented the basic design concepts for geotextile tubes filled with dredged material. The geotextile sheets are permeable, yet soil tight, so that any excess water drains from the geotextile tube. This causes the tube height to decrease, so that the tube may have to be pumped more than once in order to achieve the desired height (Leshchinsky, 1993). There are inlets at the upper part of the tube where the pumping hose is inserted.

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The number and interval of inlets are dependent upon the type of soil being used. Typical lengths and widths of geotextile tubes are 150–180 and 4–5 m, respectively, with the effective height of 1.5–2.0 m (Leshchinsky et al., 1996). Some of the most attractive advantages of geotextile tube technology are that it can be used for in-situ filling materials by hydraulic pumping; it can be also implemented with lower costs and faster construction than other technology. Because of the lower price and easier installation, geotextile tube systems can be good alternatives for hydraulic and coastal structures. Dikes and levees are among the primary uses of geotextile tubes. Dikes up to 2.0 m tall can be constructed to provide flood protection. By stacking the tubes, an even greater height can be achieved. These tubes can also be attached to the top of a floodwall to provide greater flood control (Perry, 1993). In Germany, a 15-km dike of sand-filled geotextile tubes was constructed in Leybucht. This system is proved to be a very efficient and durable method of water control (de Bruin and Loos, 1995). Groins can be very effective when used for shoreline protection. Sand-filled geotextile bags are a very reasonable alternative to other groin types. Sand-filled bags can be also used for revetments or bulkhead protection (Gutman, 1979). Environmental dredging and backfill technology using geotextile tubes was reported by Fowler et al. (1995, 2002) and Mori et al. (2002). For geotextile tubes, the major design considerations are related to the integrity of the units during release and impact, and the accuracy of placement and the stability under current and wave attack (Pilarczyk, 1998, 2000).

2. Design considerations of geotextile tubes

Making use of geotextile tubes, the major design considerations are related to the integrity of the units during release and impact, the accuracy of placement, and the stability under current and wave attack. The following design aspects are of importance.

2.1. Properties of the filling material

The physical characteristics of filling material are important factors of geotextile tube design and construction. Types of soil and degree of saturation influence the final geotextile tube shape. Field experience has demonstrated that it is possible to fill in geotextile tubes to 70% or 80% of the theoretical maximum circular diameter. The dredged material filled in geotextile tubes can be any material capable of being transported hydraulically. Naturally occurring beach or river sand is the perfect choice for structural fill.

2.2. Mechanical properties of geotextiles

The retention of fill and the structural integrity of a dredged material-filled tube are provided by the geotextile envelope. Functionally, geotextile selection is based on the geotextile's opening characteristics, which must match the fill particle size and permeability, and must have sufficient strength to resist filling pressures. A composite fabric shell is sometimes used, since it incorporates both an inner nonwoven fabric for filtration and an outer woven fabric for strength. Also, the strength of geotextile and seam strength are the major design considerations in order to resist pressures during filling and compatibility between fabric and filled material. Leshchinsky et al. (1996) presented a computing program to design geotextile tubes. Formulation of a geotextile tube, filled with pressurized slurry or fluid, is based on the equilibrium of the encapsulating flexible shell.

2.3. Hydrodynamic stability

Hydrodynamic stability is very important factor for coastal and nearshore geotextile tube construction. In order to assess the stability of the filled geotextile tube structure, current wave forces have to be estimated. Though a definitive analysis technique has not been established, a modified Minikin approach, as outlined in the US Army Corps of Engineers' SPM, may provide a reasonable approach to assessing the stability of filled units under wave loading.

3. Prediction method for geotextile tube shape

To predict of tube shape filled with coarse-grained material is easier than that with fine-grained material, because of immediate settlement and effective free drainage of coarse-grained material. In case of fine-grained material, the consolidation process is more complicated due to suspending fine particles, clogging of geotextile, nonhomogeneous slurry, and staged filling process. There are two approach methods to predict the tube shape variation with consolidation process. The volume reduction method (VRM) provides the tube height variation with desired density of slurry based on the volume–weight relationship. However, the settling and self-weight consolidation method (SSCM) provides the variation of settling velocity (V_s) and self-weight consolidation coefficient (C_F) with initial water content, and it is the time domain parameter based on the laboratory SSCC tests. All these prediction methods are briefly described.

3.1. Volume reduction method

The governing mechanism of this approximation is that the tube only changes its height during the consolidation process. Also, the approximation options of computer program GeoCoPS are two shape types (elliptical and rectangle); it was selected by the magnitude of height drop, desired density, and final tube shape. To simplify the boundary condition and influencing factor, the following assumptions are considered in these approaches: (1) the consolidating material has one-dimensional movement;