Geosynthetic Support Systems over Pile Foundations

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Abstract

In recent years, geosynthetics have been used in combination with pile or column systems to support embankments over soft foundations. A number of research activities on this application have been performed in the past several years. This paper reviews some of these activities and focuses on preliminary results of current research being conducted by the authors.

Introduction

Geosynthetic-reinforced embankments over piles with caps or columns (Figure 1) as a ground improvement technique have been used for more than two decades. Geosynthetic reinforcement enhances load transfer from soil to columns, reduces total and differential settlements, and minimizes the differential settlement at the base of the embankment to be reflected to the surface. This technology is most suitable for situations where soft soil is underlain by a stiff soil layer or bedrock, time is of the essence, and limits on total and differential settlement must be controlled. They have been mainly used for bridge approach embankments and roadway widening. Timber piles, augered piles, vibro-concrete columns, and deep mixed columns are the deep foundation systems used in column supported embankment applications. Geosynthetics are used in either a single layer or multiple layers (generally three). A single high-strength geotextile or geogrid layer functions as a tensioned membrane, whereas multiple low-strength geogrids spaced in granular fill form a load transfer platform functioning as a beam. Russell and Pierpoint (1997), Han (1999), and Collin (2003) provide reviews of the design methodology for this technology.

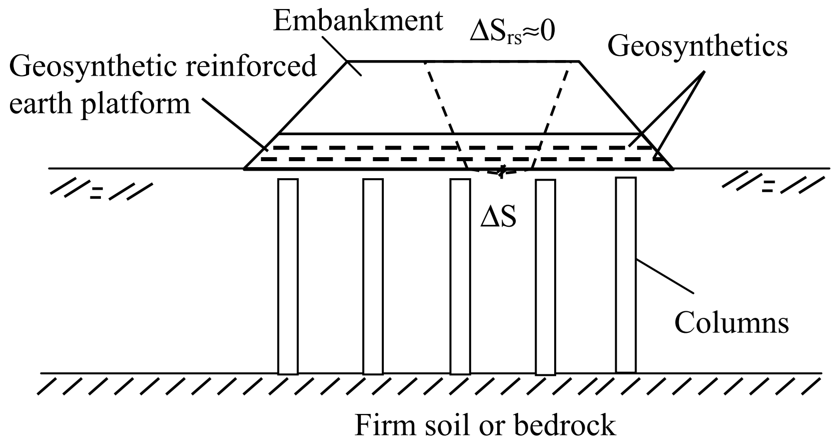

Figure 1. Geosynthetic reinforced column supported embankments.

Design of geosynthetic-reinforced fill platforms above pile caps or columns involves the estimation of stresses applied on the geosynthetic layers based on soil arching, and the calculation of the required tensile strength of geosynthetic layers based on their allowable strain level and membrane theory. Different soil arching models have been proposed and used in the design, which include Marston and Anderson (1913) or Terzaghi (1943)'s trench model (for example, British Standard BS 8006, 1995) as shown in Fig. 2(a), two or three-dimensional prism model (for example, Fluet et al., 1986; Carlsson, 1987; Schmertmann, 1991; Miki, 1997) as shown in Fig. 2(b), and semi-spherical crown model (Hewlett and Randolph, 1988) as shown Fig. 2(c). These models are used for the fill platform containing a single geosynthetic layer. For multiple geogrid layers in the fill platform, granular fill is required for multiple geogrid layers to form a load transfer platform. Collin (2003) detailed the design procedures of the load transfer platform. In most design methods, the soil resistance underneath geosynthetic layers is ignored. Tensioned membrane theories are used to calculate the required tensile strength of geosynthetics based on an allowable tensile strain (Giroud et al., 1990 and British Standard BS 8006, 1995). Han (1999) reported that the percent coverage of pile caps or columns for most constructed projects ranged from 10% to 30%.

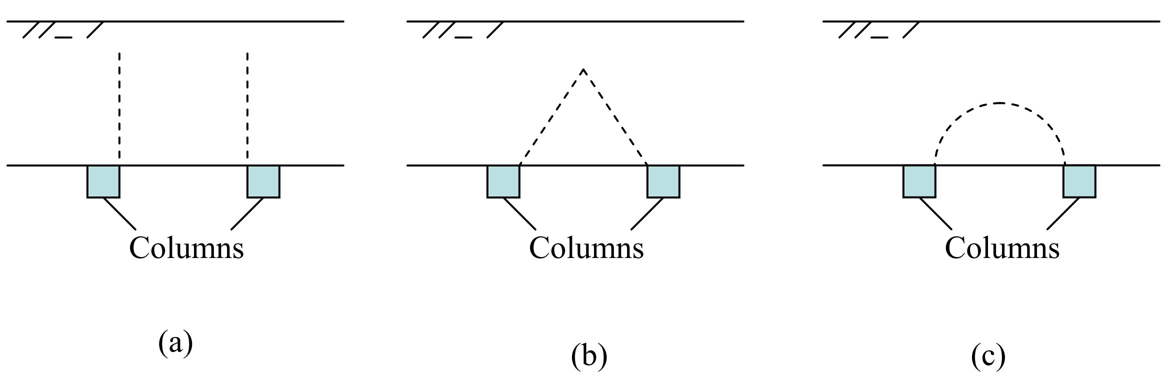

Figure 2. Soil arching modeling.

Recent Research Activities

Several research activities have been going on in the United States in the past few years, which include the FHWA funded project, "Geosynthetic Reinforced Pile Supported (GRPS) Embankments," by Briaud; the FHWA pooled fund project, "Geosynthetic Reinforced Column Supported Embankments," by Collin and Han; the National Deep Mixing Program project, "Development of Design Charts for Geosynthetic-Reinforced Embankments over Deep Mixed Columns," by Han; and the industries-sponsored project, "Geosynthetic-Rammed Aggregate Pier Supported Embankment," by White. This technology has been adopted in several recent roadway projects, including the I-95/Route 1 interchange project (Stewart et al, 2004), an approach embankment of US Route 9 in New Jersey (Mankbadi et al, 2004), and a road for a new residential section of the Kingsmill development in Williamsburg, Virginia (Collin et al, 2005). Several papers and reports have been published to provide the state of the art or practice review of this technology (for example, Li et al., 2002; Han, 2003; Collin, 2003; and Han et al., 2004).

Research in Progress

The FHWA pooled fund project, "Geosynthetic Reinforced Column Supported Embankments" began in September 2003. The scope of this research is to understand the behavior of geosynthetic-reinforced column-supported embankments using numerical methods and to develop design guidelines for column supported embankments. Initially, a literature review was conducted to understand the state of the art and practice of this technology. Second, a case study was identified and used for calibrating 3D numerical models. Based on the comparisons between the field data and the numerical results, Huang et al. (2005) indicate that the numerical methods can reasonably predict the maximum settlement at the base of the embankment and the tension in the geosynthetic layers. Numerical studies found that the maximum tension in a single geosynthetic layer develops at the edges of the pile caps or columns. In a three-geosynthetic layer system the maximum tension in the lower layer developed in the middle of the span, however, the maximum tension in the top layer developed at the edges of the pile caps. This behavior implies the geosynthetic-reinforced fill platform acts as a beam as shown in Figure 3. The parametric studies to evaluate the possible factors influencing the behavior of this system are underway. Design guidelines will be proposed based on the numerical analyses and available field data.

Acknowledgement

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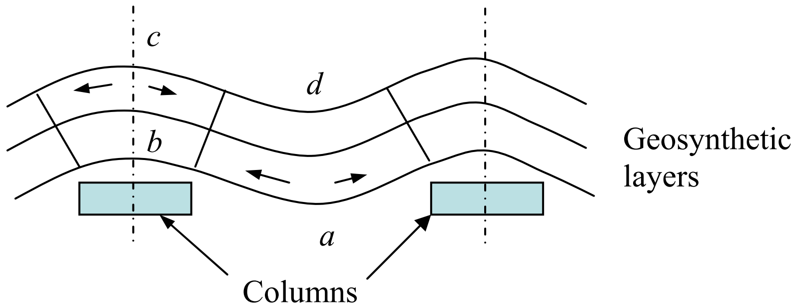

Figure 3. Deformation of multiple geosynthetic layer system (Huang et al, 2005).

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