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Performance evaluation of two silt fence geotextiles using a tilting test-bed with simulated rainfall

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ABSTRACT

This paper presents the results of the investigation of the performance efficiencies of silt fence fabrics in turbidity and sediment concentration removal, and the determination of flow-through-rate on simulated construction sites in real time. Two silt fence fabrics, (1) a woven type and (2) a nonwoven type, were subjected to material index property tests and a series of field-scale tests. The fabrics were tested for removal efficiency by varying the rainfall intensities and events for different embankment slopes on a tilting test-bed. Collected influent and effluent samples were analyzed for sediment concentration and turbidity, and the flow-through-rate for each fabric was evaluated. Test results revealed that the woven and nonwoven silt fence achieved 14 and 52 percent average turbidity reduction efficiency, and 23 and 56 percent average sediment concentration removal efficiency, respectively. Evaluation of sediment concentration reduction based on percent removal does not correctly account for the sediment concentration transported and deposited downstream. Fabric flowrates were functions of the rainfall intensity, embankment slope and field conditions, and fluctuates with every rainfall event.

1. Introduction

The impacts of sediment transport from construction sites have been widely investigated and attributed to the lack of erosion control practices on large construction sites (Fifield, 2004; Hayes et al., 2005; Smoot et al., 1992; USEPA, 1999b). The average concentration of solids increases dramatically during active construction when compared to pre-construction and post-construction levels (Cleveland and Fashokun, 2006; Owens et al., 2000). It was estimated that over four billion tons of sediment are transported to water bodies, and approximately 10 percent of this comes from erosion occurring at construction sites in the United States (Randolph et al., 1969). The sediments are laden with pollutants which when deposited result in costly damage to aquatic areas and to both private and public land (Bilotta and Brazier, 2008; Rickson, 2006). To minimize soil losses and its detrimental off site impact, regulatory agencies require erosion and sediment control practices at construction sites and in post-construction plans (USEPA, 1999a, 2006).

The minimal erosion and sediment control measures required in most instances are perimeter controls (silt fences and straw bales) and tracking pads (crushed stone or gravel at vehicle access points). Silt fence is defined as a vertical temporary barrier made of geosynthetics filter fabric installed along the perimeter of disturbed lands or exposed surfaces to control sediment-laden sheet flow from leaving the site (FDEP, 2008). The function of silt fence is to decrease the velocity of sheet flow or site runoff, detain the water to allow for settling of suspended solids, and retain sediment on site. However, silt fence fabrics do not effectively filter sediment out of runoff except for larger particles of sand (Barrett et al., 1998). Silt fence effectiveness is dependent on the ability to create small containment system to allow for deposition of suspended particles in the water (FDEP, 2008; Risse et al., 2008).

Silt fence fabric is effective in reduction of total suspended solids (TSS), but less effective for settleable solids and turbidity (Horner et al., 1990). On the other hand, Barrett et al. (1998) showed that filtration was insignificant in the removal of solids concentrations, and the removal was mainly due to the particle settling behind the silt fence, which is a function of the geometry of the upstream pond, fabric hydraulic properties, and silt fence maintenance. The inflow sediment significantly clogged the fabric and resulted in rapid rise in backwater height (Wishowski et al., 1998). The trap efficiency decreased as particle size became smaller and was not

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significantly affected by flow rate but by influent concentration. Laboratory studies showed no observable trend of water permeability and filtration efficiency for filter fabrics (Wyant, 1981), and the accumulation of the soil particles influenced the retention ability (Raisinghani and Viswanadham, 2010).

Geotextiles, as erosion and sediment control barriers, play the role of providing filtration of soil particles from leaving a site and yet allow the flow of water through them (Lamy et al., 2013). Kouwen (1990) describes geotextiles as effective filtration fabric, and that less permeable fabrics results in greater efficiencies with potential for clogging and overtopping. Geotextile filtration efficiency is a function of both the geotextile characteristics and sediment sizes, as the apparent opening size (AOS) and the permittivity are not effective indicators of the filtration efficiency performance of silt fence fabrics (Crebbin, 1988; Quaranta and Tolikonda, 2011). Investigation of the mechanism of geotextiles in erosion prevention, sediment control functionality and prediction of field performances revealed that index properties such as grab tensile strength, UV stability, AOS, and permittivity tests could not provide reliable prediction of field performance (Barrett et al., 1998; Chew et al., 2003; Chopra et al., 2010; Narejo, 2003; Risse et al., 2008; Suits and Hsuan, 2003). The performance of silt fence is influenced by the fabric type (Moraci et al., 2012; Palmeira et al., 2012; Rawal and Saraswat, 2011), installation (Barrett et al., 1998; Britton et al., 2000; Fannin et al., 1996), and the permeability of the filter cake on the fabric (Aydilek and Edil, 2002, 2003; Weggel and Dortch, 2012; Weggel and Ward, 2012). Fisher and Jarrett (1984) concluded that a compromise was necessary between a fabric's ability to retain soil particles and its ability to transmit water for any fabric system in contact with detached soil particles.

Investigation on the effectiveness of silt fence has demonstrated the strong need for field-scale performance studies (Britton et al., 2000). Most of the previous studies were performed using flumes, test beds with fixed slopes, or monitored storm events. For the monitored storm events, samples were collected after each storm event from standing pool upstream and downstream of the silt fence (Barrett et al., 1998). While these studies have provided insight into the performance of silt fence fabrics, an active storm event would definitely impact the performance of the fabrics in turbidity and sediment concentration reduction. To this end, the present study investigated active rainfall events with different intensities and embankment slopes to evaluate the real time performances of silt fences.

Field tests were designed to determine the field performance, installation, filtration capacity, and flow-through rates (hereafter referred to as flow rates) of woven and nonwoven silt fence barrier using a rainfall simulator on field scale testing bed. The tests involve series of pilot-scale tests for different rainfall intensities on compacted sandy soil embankment slopes in order to simulate the actual performance of silt fence in real time operational conditions. The research objectives of this study are to evaluate the effectiveness and efficiency; determine the inherent problems in current practice; and compute the flow rates of silt fences when used as temporary sediment barriers. Analysis of tests results will further provide means of developing the relationship between the silt fence barrier flow rate and filtration efficiency.

2. Test equipment, materials and setup

The investigations were conducted using the test bed and rainfall simulator located at the University of Central Florida (UCF) Stormwater Management Academy Research and Testing Laboratory (SMARTL).

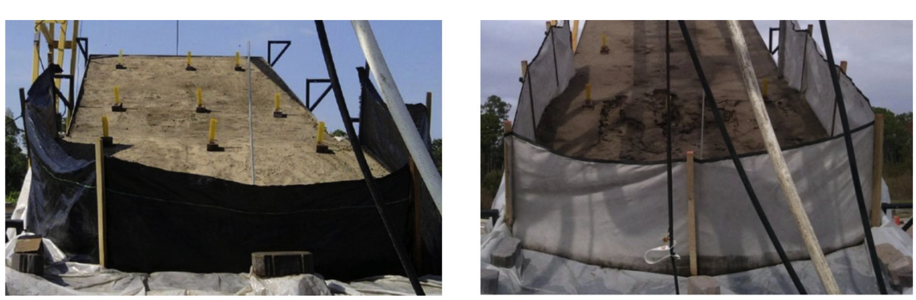
2.1. Materials

There are numerous silt fence fabrics available, but the commonly available and accepted silt fence is the traditional monofilament geosynthetics used at most sites undergoing construction activities. Studies on this type of silt fence have previously shown frequent failures in achieving the required performance targets (Barrett et al., 1998; Faucette et al., 2009; Wishowski et al., 1998). In response to these findings, a nonwoven belted silt retention fabric (BRSF) was introduced by Silt Savers, Inc. The BSRF is designed to retain more silt and reduce turbidity and suspended solids than the traditional woven monofilament silt fence fabric (Risse et al., 2008). However, studies showed that proper installation and regular maintenance are essential to successful removal of sediment from runoff by any type of silt fence (Barrett et al., 1998; Kouwen, 1990).

The two silt fence fabrics investigated were a woven monofilament polypropylene fabric (ASR 1400) and nonwoven polyester (BSRF), shown in Fig. 1(a) and (b), respectively. ASR-1400 is an engineered geotextile, a circular woven polypropylene fabric, stabilized to resist degradation due to ultraviolet exposure, nonbiodegradable and resistant to chemicals, mildew and insects usually encountered in soils (Assurence Corp., 2006). On the other hand, BSRF is a nonwoven biodegradable spun-bound polyester reinforced with coarse mesh-like fiberglass scrim sandwich between layers (Risse et al., 2008).

2.2. Tilting test-bed

The Aluminum test-bed used for testing is 2.4 m wide by 9.1 m long by 12.7 cm deep and attached to a tilting system with a pivot at one end and a hydraulic mechanism to adjust for different slopes, as shown in Fig. 2. A single hydraulic system is used to set a slope on the test bed with a maximum obtainable slope of 1:2 vertical to horizontal ratio. The test bed is connected to a collection of tubing and horizontal reservoir designed with the capability to set a



(a) (b)

Fig. 1. Two silt fence geotextiles investigated: (a) woven and (b) nonwoven.