Geotextiles and Geomembranes 34 (2012) 116–130

Contents lists available at SciVerse ScienceDirect

Geotextiles and Geomembranes

journal homepage: www.elsevier.com/locate/geotexmem

Combined use of geocell reinforcement and rubber–soil mixtures to improve performance of buried pipes

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ARTICLE INFO

Article history:
Received 25 May 2011
Received in revised form
7 April 2012
Accepted 22 May 2012
Available online xxx

Keywords:
Soil surface settlement
Rubber
Repeated loading
Buried pipes
Reinstatement trench
Geocell reinforcement

ABSTRACT

Service trench provision and maintenance of buried pipes represent major cost items in the utilities industry. Using recycled material in order to optimize the design of the buried pipe system can lead to significant cost reductions, but only if performance is not degraded. The main purpose of the paper is to investigate the mitigation of strain in buried flexible service pipes and of the settlement of backfill over such pipes by the use of geocell reinforcement (as 3D-inclusion reinforcement) with rubber–soil mixtures under repeated loading conditions. Two rubber sizes (namely chipped and shredded rubbers), three different percentages of rubber content in the mixture, two positions for soil–rubber mixture inside the trench, four levels of repeated loading and the addition of geocell reinforcement over the pipe are the variables considered. Soil surface settlement, vertical diametral strain of the pipe (as an indication of pipe wall deflection) and stress distribution in the trench, especially on pipe's crown, are assessed and evaluated. Both cumulative and resilient strains are considered. Using a material with high resilience, like the rubber–soil mixture, could lead to some critical issues that should be considered. These include the larger settlement of the soil surface, transfer of a larger pressure onto the pipe and, consequentially, greater pipe wall strain. For the chipped rubber and soil mixture, the pipe has the highest strains under the cyclic loading irrespective of the amount of rubber in the soil. However, the shredded rubber and soil mixture, dependent on the amount of rubber content, is able to reduce the soil settlement and plastic pipe's diametral strain, attenuating the pipe's accumulating strains and, finally, protecting the buried pipe from fatigue under repeated loadings. This benefit is enhanced by the combined action of geocell reinforcement over rubber-modified soil. According to the results, the minimum soil surface settlement and vertical diametral strain are provided by 5% of shredded rubber–soil mixture placed over the pipe with a geocell, giving values of, respectively, 0.30 and 0.53 times those obtained in the unreinforced and untreated soil.

1. Introduction

Buried pipeline systems are commonly used to transport water, sewage, natural oil/gas and other materials. They are classified as lifelines since they carry essential materials for the support of human life (Choo et al., 2007). Repeated vertical loads like traffic loads present a severe hazard. For this reason, researchers have attempted to understand pipe behaviour under different loadings so as to mitigate the hazardous effect of repeated loading on buried pipes. Although there are some standards and instructions for design (e.g. ASTM D 2321-08; BSI, 1980), installation and maintenance of buried pipes, nevertheless backfill material optimization needs to be studied, particularly in the case of reinforced backfill material and rubber–soil mixture.

In recent years, environmental concerns and a greater willingness to consider unconventional solutions means that lightweight materials such as fly ash, tire rubbers, geofoam, wood fibre and reinforcement materials like geogrid, geotextile and geocell are now considered (Consoli et al., 2009a,b; Tanchaisawat et al., 2010; Diambra et al., 2010; Lovisa et al., 2010; Edinçliler and Avhan, 2010; Falorca and Pinto, 2011).

Recently, the beneficial effects of using three-dimensional reinforcement to increase the bearing capacity of soil has been clearly demonstrated by several investigators (Dash et al., 2007; Madhavi Latha and Rajagopal, 2007; Sitharam et al., 2007; Zhang et al.,

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doi:10.1016/j.geotexmem.2012.05.004