International Journal of Geosynthetics and Ground Engineering (2022) 8:57
https://doi.org/10.1007/s40891-022-00397-9

ORIGINAL PAPER

Waste Rubber–Soil Mat for Protection of Structures from Earthquake-Induced Liquefaction

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Received: 22 May 2022 / Accepted: 13 August 2022

Abstract
Due to the rising amount of waste rubber products, there is an urge to recycle these products and reduce waste disposal. Crumb rubber tyre in the sand decreases pore water pressure, creating a good drainage path and reducing liquefaction in saturated dense sand. This paper investigates the effect of the waste tyre and soil mixture (WTSM) layer around the piles in mitigating earthquake-induced liquefaction through finite element analysis in OpenSees platform. The effectiveness of this technique in reducing pile response is investigated through a parametric study with varied depth and thickness of the WTSM layer. It is estimated that a reduction in pile response is achieved with an increase in WTSM volume. It is also estimated that placing the same volume of WTSM layer depth-wise gives better control. Finally, for closely spaced piles WTSM mat of 1–1.5 m depth is proposed for liquefaction-induced pile damage control for buildings. Huge stock of scrap tyres may be used for pile response reduction due to liquefaction as recycling of waste tyre.

Keywords Liquefaction · Pile foundation · WTSM · Lateral spreading · OpenSees

Introduction

Rapid demand for rubber usage in vehicle production and medical, engineering, and household applications increases rubber waste generation, leading to environmental problems. Disposal of these wastes is becoming a burden to the municipal authority and lack of awareness among people makes the problems of waste rubber products disposing worsen. Landfill dumping with discarded rubber and open burning is the cheapest and easiest method of disposing of waste rubber, but these lead to water, air, and soil pollution. The poor disposal of rubber products becomes a major threat to human health and the environment [1]. Also, rubber disposal is costly because of rising land costs [2]. Hence, there is an urge to recycle these products and reduce waste disposal. Scrap rubber tyre chips are widely used as alternate materials in many civil engineering applications as aggregates [3, 4]. Considering the damping characteristics of rubber, researchers tried using shredded rubber in soil [5, 6] for earthquake protection of buildings. Some researchers used tyre chips instead of pure rubber around the foundation [7–9] as seismic base isolation. They reported substantial response reduction in the structures and the foundations when subjected to earthquake excitation. The feasibility of using shredded rubber mixed with sand as a natural base isolator was investigated analytically by Tsang [7] and Nanda et al. [8]. The geotechnical and mechanical properties of soil mixed with tyre chips increase soil's flexibility and damping characteristics [10–13], reducing the earthquake energy transmission to the superstructure. Rubber in the form of tyre chips mixed with sand for 5 m thickness around the piles to isolate the seismic effect is analysed by Santoni [14]. Around 40% efficiency for roof acceleration in five-storey buildings is achieved with this isolation system.

Liquefaction is one of the significant issues in geotechnical engineering due to its damaging effect on structures and facilities during earthquakes. During potential earthquakes, pore water pressure increases and balances the weight of the soil, reducing the shear strength and bearing capacity. Pile foundation is the solution to this structural failure due to earthquakes. Still, they suffer large-scale damage because

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Published online: 05 September 2022