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ScienceDirect

Procedia Engineering 193 (2017) 305 – 312

Procedia Engineering

www.elsevier.com/locate/procedia

International Conference on Analytical Models and New Concepts in Concrete and Masonry Structures AMCM'2017

Reduction of vibrations applied on structures - results of chamber tests with the use of tire derived aggregate

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Abstract

This paper presents results of laboratory (medium scale) tests on models simulating a 'concrete footing - subsoil' system. Their goal was to investigate the effectiveness of a cushion made of scrap tire rubber granulate to reduce vibrations applied on the concrete footing. The pad foundation was placed in two types of subsoil: one consisted of sand, the other of sand and a tire rubber layer placed directly under the footing. The models were built in a box 73 x 73 cm wide and 50 cm high, which was then subjected to vibrations by means of a vibration table. The kinematic excitation of vibrations and the response of the footing were examined in the domains of time and frequency. The analysis allowed to estimate the effectiveness of reduction of vibrations dependently on amplitude and frequency of excitation. Additionally, the phase angle between the excitation and response of the model was measured for the main frequency of vibrations. It has been proved that the effectiveness of the scrap tire rubber layer does not depend substantially on the amplitude of excitation, but it does increase for higher frequencies of excitation.
The tested solution may constitute an alternative for traditional vibration isolation systems with vertical screens placed close to the source of vibrations or isolations built-in the structure of a building. Its application will be cheap, easily accessible and sustainable.

Peer-review under responsibility of the scientific committee of the International Conference on Analytical Models and New Concepts in Concrete and Masonry Structures

Keywords: vibration suppression; concrete footing, scrap tire rubber

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doi:10.1016/j.proeng.2017.06.218

1. Introduction

Design of every structure, that is to be located close to a source of mechanical vibrations, requires taking some steps in order to reduce the amplitudes of vibrations transferred from the ground to the foundation. One of the solutions applied in such a case may be a modification of the soil parameters in the form of a resilient layer (cushion) designed for vibration suppression built directly under the foundation. A sustainable approach to civil engineering would demand a use of some waste material for this purpose and a perfect choice seems to be rubber derived from scrap tires.

Since 2006 disposal of scrap tires into landfills has been banned in the European Union, forcing the producers and importers to recover and recycle their products. In Poland, the recovery is realized mostly by burning the End-Of-Life tires in cement kilns, which contributes to the increase of CO_2 emission into the atmosphere. Much better, from the ecological point of view, is the recycling of the shredded car tires e.g. in the way mentioned above - as a vibration isolation [1]. It may take a form of a dense, and relatively thin, mat that may be applied e.g. under machine foundations or, in a loose state, the shredded tire rubber can be applied as an isolation layer surrounding a building foundation. This kind of solution was tested e.g. by Hazarika et al [2] in a large scale experiment (1:10 model), where rubber chips formed a backfill of a caisson type quay wall subjected to acceleration imitating the 1995 Hyogoken Nanbu earthquake. The rubber cushion prevented liquefaction and greatly reduced the seismic load. The rubber-soil mixture applied as a layer under a residential building was analyzed numerically by Tsang et al [3]. They subjected the model to strong ground motions of three different earthquakes and observed that the horizontal acceleration of the roof and footing of a low-to-medium rise building was decreased by about 40 – 70% as the thickness of the cushion changed from 5 to 15 m.

The above reports were the inspiration of the research presented in this paper. Its goal was to estimate the efficiency of a rubber granulate layer placed under a concrete footing for suppression of vibrations applied to the ground, which might simulate e.g. a concrete or masonry building located next to a busy road or railway or subjected to vibrations caused e.g. by nearby soil compaction or other soil strengthening works.

2. Methodology

2.1. Laboratory models

The models were prepared in a laboratory scale. An open box made of plywood 2 cm thick of internal dimensions: 73 x 73 x 50 cm was constructed and attached to a vibration table (see Fig. 1). To reduce reflection of vibration waves from the sidewalls an insulation layer (a mineral wool board Isover TDPT 15 mm thick) was laid inside the box, which was next covered with foil. The weight of the complete box was equal to 33.15 kg. The amplitude of vibrations was controlled with a knob on the control panel of the table. Its specific positions (from the smallest to the greatest possible amplitude) were marked as Levels 1 - 4 (see Fig. 1 d), which corresponded to the amplitudes presented in 0. The box was filled with 4 layers (each 10 cm thick) to form a subsoil for a foundation. First two layers and the last one were made of 90 kg of sand. The third one, on which the concrete footing was placed centrally, was made either of 90 kg of the same sand or of 30 kg of rubber granulate surrounded by a geotextile interfacing. This way two different models were built: model SA with 30 cm of sand below the footing and model SA-R with 20 cm of sand and 10 cm of tire rubber granulate directly under the foundation. The footing, weighing 4.55 kg, had a square base 14.4 cm wide. Both the models are presented in Fig. 1 a and Fig. 1 b.

In order to measure excitation and response of the footing in vertical direction two sensors were used: the first one was fixed to the bottom of the box and the second was attached to the top of the footing. Sensitivity of the sensors was equal to 100 mV/g, their measurement range was 50 g. Vertical accelerations were sampled with frequency f_s of 2048 Hz.

2.2. Materials

The basic material forming the subsoil in the models was clean medium sand with grading between 0.1 mm and 5 mm. It was uniform - its uniformity coefficient C_u = 3.0 and coefficient of curvature C_c = 1.2. It was of fluvial