

Compound Soil with Tyre Chips as a Sustainable Fill in Seismic Zones

Panu Promputthangkoon and Adrian FL Hyde
Geotechnical Engineering
Department of Civil and Structural Engineering
University of Sheffield, UK

ABSTRACT

Reclaimed land constructed in seismic zones is prone to liquefaction because conventional construction practice tends to produce a loose to medium deposit. At the same time discarded tyres have become an increasingly problematic global problem whose disposal is posing dangers to the environment. This paper attempts to overcome both problems by means of mixing tyre chips with sand and using them for landfill purposes. A computer-controlled cyclic triaxial testing system has been used to determine the liquefaction strength of pure sand and sand-rubber mixtures. The results show that for 5% to 30% of tyre chips by volume, the liquefaction strength actually decreases compared to that of pure sand samples. However, when the proportion of tyre chips is increased to 40% and more, the results show a significant improvement in liquefaction resistance.

KEY WORDS: Liquefaction; sand; tyres; earthquake; cyclic, reclaimed; triaxial.

INTRODUCTION

In element tests under undrained conditions a soil is considered to have liquefied when the generated pore water pressure is approximately equal to the initial effective stress. During liquefaction the soil completely loses shear strength and stiffness and behaves like a viscous fluid having the unit weight equal to a saturated soil. In such conditions, superstructures having a unit weight greater than those of the liquefied soil will sink. On the other hand, buried structures whose unit weight is smaller, will float (JGS, 1998). The probability of damage is therefore high.

In geotechnical design not only is the shear strength considered, but also the settlement and deformation must be included. For liquefaction analysis, even if the ratio of pore water pressure Δu to consolidation pressure σ'_{3c} is still below 1.0, i.e., $\Delta u/\sigma'_{3c} \cong 0.6 - 0.8$, the deformation due to softened soil may be sufficient to cause damage. Thus, it is customary to apply a limiting strain level in a liquefaction analysis.

For cyclic triaxial tests a cyclic stress ratio CSR has been defined as $q_{cyc}/2\sigma'_{3c}$ where q_{cyc} denotes the single-amplitude of cyclic axial stress

(Hyodo et al., 1998; Hyde and Higuchi, 2005). The cyclic strength (Ishihara, 1993) is defined as the magnitude of the CSR required to produce 5% of either double-amplitude axial strain $\varepsilon_{a,DA}$ in case of stress reversal or 5% of axial plastic strain $\varepsilon_{a,P}$ in case of no stress reversal after 20 cycles of uniform load application.

Reclaimed land refers to man-made land or artificial island that is constructed by depositing fill materials, normally soil, in open water areas such as oceans, lakes, and harbours. Examples of reclaimed land are waterfront developments, offshore artificial islands, and offshore airport construction. Generally, the conventional practice of reclaimed land construction produces loose to medium sediments (PHRI, 1997). If such reclaimed land is to be constructed in seismic zones, then these sediments are very susceptible to liquefaction when encountering earthquakes and vibration.

Recently, discard tyres have become an increasing problem around the world because disposing of them in open areas is a danger to the environment and humans. They are vulnerable to fire and subsequently may contaminate ground water. As a result, for example, disposing of whole used tyres has been prohibited by a new EU Landfill Directive since July 2003 (Khalid and Artamendi, 2004). Thus, making use of them needs to be considered imaginatively and the solution must be sustainable.

This paper investigates sustainable solutions for landfill materials used for reclaimed land construction in earthquake prone areas. The cyclic strength of liquefiable sand was determined using a computer-controlled cyclic triaxial testing system. Tyre chips were then mixed with the sand, and the liquefaction characteristics of pure sand and sand-rubber samples were compared.

TEST MATERIALS

Leighton Buzzard 16/30 sand obtained from WBB minerals, UK, was selected because it is liquefiable. It is a silica sand having D_{50} of 0.7 mm, brown colour, sub-rounded to sub-angular grains. The maximum and minimum void ratios were 0.821 and 0.460, and $G_s = 2.66$.

The tyre chips CT0515 were obtained commercially from Charles Lawrence International, UK. They had an average particle size D_{50} of 1.2 mm and uncompacted bulk density of 0.432 Mg/m^3 . The specific gravity of tyre chips was 1.16, which is comparable to ASTM D6270