RECYCLING OF END-OF-LIFE TYRES IN SEISMIC ISOLATION FOUNDATION SYSTEMS – ASSESSMENT OF POTENTIAL LEACHING

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Over 6.3 million waste tyres are produced annually in New Zealand (Tyrewise, 2021), leading to socioeconomic and environmental concerns. The 2010-11 Canterbury Earthquake Sequence inflicted extensive damage to ~6,000 residential buildings, highlighting the need to improve the seismic resilience of the residential housing sector. A cost-effective and sustainable eco-rubber geotechnical seismic isolation (ERGSI) foundation system for new low-rise buildings was developed by the authors. The ERGSI system integrates a horizontal geotechnical seismic isolation (GSI) layer i.e., a deformable seismic energy dissipative filter made of granulated tyre rubber (GTR) and gravel (G) – and a flexible rubberised concrete raft footing. Geotechnical experimental and numerical investigations demonstrated the effectiveness of the ERGSI system in reducing the seismic demand at the foundation level (i.e., reduced peak ground acceleration) (Hernandez et al., 2019; Tasalloti et al., 2021). However, it is essential to ensure that the ERGSI system has minimal leaching attributes and does not result in long-term negative impacts on the environment.

Aims

The overall aim of the portion of the study presented in this abstract is to provide an update on insights on subsoil/groundwater contamination due to the use of GTR in the ERGSI foundation system.

Method

Tests (Table 1) were undertaken to idenitfy the potential for the GTR:G mixtures to leach contaminants. Rigid-soft granular mixtures were prepared using a combination of uniformly graded round (G_{RND}) and angular (G_{ANG}) gravels and large (GTR_{LRG}) and small (GTR_{SML}) tyre rubber particles.

Test #	*Test media*	*GTR (% by volume)*	*Gravel (% by volume)*
1-3	$GTR_{LRG}G_{RND}$ (w)	40	60
4-6	$GTR_{SML}G_{RND}$ (w)	40	60
7-9	$GTR_{LRG}G_{ANG}$ (w)	40	60
10-12	$GTR_{SML}G_{ANG}$ (w)	40	60
13-15	GTR_{LRG} (w)	100	0
16-18	GTR_{SML} (w)	100	0
19-21	G_{RND} (w)	0	100
22-24	G_{ANG} (w)	0	100
25-27	G_{RND} (u)	0	100
28-30	G_{ANG} (u)	0	100
31	DI water (blank/control)	0	0
Leaching test media (left to right: GTR_{SML} 1.6 mm D_{50}, GTR_{LRG} 3.7 mm D_{50}, G_{RND} 5.6 mm D_{50}, G_{ANG} 4.2 mm D_{50}) 			

Table 1: Leaching tests undertaken in this study (GTR: granulated tyre rubber, G: gravel, LRG: large, SML: small, RND: round, ANG: angular, w: washed, uw: unwashed)

For each test, the required media were placed in 3 L wide mouth glass bottles and filled with 5 L (Tests #1-6) and 2 L (Tests #7-31) of DI water. For Tests #1-12 100g GTR and 355g gravel was used. The bottles were sampled periodically (Day 0, 1, 2, 4, 7, 10, 14, 17, 21, 24, and 28). pH and electrical conductivity (EC) of the leachate were recorded using a Hach HQ40d meter. Leachate samples were filtered (Millex® HA filter unit, 0.45 μm MF-MilliporeTM PVDF membrane, Merck Millipore), acidified and refrigerated until analysis. Components of interest analysed in the leachate included: TOC, Zn, Cd, Cr, As, K, P, Na, Mn, Fe, Ca, Mg, Al, Cu, and Pb. TOC was measured using a Shimadzu TOC high temp combustion analyser. Inorganic constituents were measured using Inductively Coupled Plasma – Mass spectroscopy (ICP-MS).

Results

pH of the leachate was relatively stable during the tests and there was no significant difference in the pH between the tests. Leaching from the GTR and G_{ANG} mixes caused the greatest increases in EC, with the larger surface area of GTR_{SML} causing increased leaching and, thus, the greater EC of the two mixes. TOC leached from GTR_{SML} (68.7 ± 18.4) was greater than that leached from GTR_{LRG} (25.4 ± 1.22 mg) (Figure 1). Greater amounts of TOC were leached out of G_{ANG} (washed: 4.21 ± 0.20 mg, unwashed: 4.01 ± 0.24 mg) compared to G_{RND} (washed: 0.63 ± 0.26 mg, unwashed: 0.55 ± 0.12 mg). Leaching of Ca, Na, Mg and K was attributed to the greywacke gravel (composed of feldspar minerals) and leaching of Zn (Figure 2) was attributed to the GTR. Zn was primarily leached from the GTR, with the higher surface area of GTR_{SML} leading to higher Zn levels (Test#4-6: 4.80 ± 0.56 mg, Test#10-12: 0.73 ± 0.04 mg) compared to GTR_{LRG} (Test#1-3: 0.95 ± 0.22 mg, Test#7-9: 0.12 ± 0.04 mg). The GTR also leached small amounts of Co (≤ 10^{-2}), Cr (≤ 10^{-3}), Ni (≤ 10^{-3}), As (≤ 10^{-4}), Cd (≤ 10^{-4}), Pb (≤ 10^{-4}).

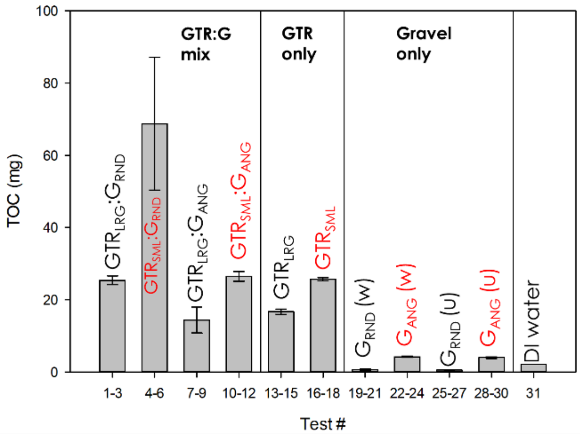

Figure 1: TOC (mg) of leachate

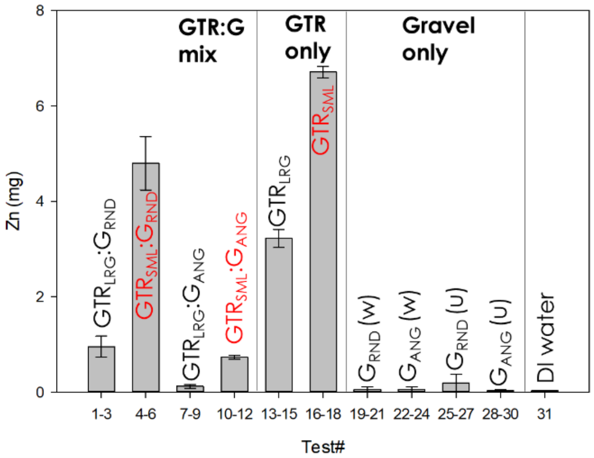

Figure 2: Mass of Zn (mg) in leachate

Key findings from this research show that leaching was dependent on the size of GTR and the gravel used. Greywacke is a variety of argillaceous sandstone that is made up of quartz, lithics, and minor feldspars, and these assorted minerals account for the various elements leached from it. In the presence of GTR, the levels of Na, Mg, and Ca in the leachate were increased, while the levels of As were reduced. Increased surface area of the angular gravel and the “raw” nature of those exposed broken surfaces allows for greater weathering of the minerals making up the G, leading to increased chemical leaching. The G_{RND} showed consistently lower levels of most of the elements tested for (except for P). The naturally rounded nature of the gravel means that it has already undergone a period of weathering in the environment and the easily leached/weathered minerals will have already been lost from the gravel’s surface. The washed G_{RND} showed higher levels of elements in the leachate than the unwashed G_{RND}, due to the washing and oven drying processes that the media was subjected to, drawing elements from within the gravel to the outer surface. The leaching data for these compounds, particularly for the smaller size fraction of GTR, provides the data required to develop a framework with specific design criteria for ERGSI foundation systems so that leaching to groundwater and surface water is minimised (e.g., pre-treatment, confinement of leaching materials).

References

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