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# Behaviour of geotextile filters in armoured slopes subjected to the action of waves

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ABSTRACT

Geotextile filters can be used in several geotechnical and geoenvironmental applications. Regarding the protection of banks or slopes against erosion caused by the action of waves, these materials can be employed under revetments and armour layers. This paper presents results of large scale tests on armoured slopes where geotextile and granular filters were employed. A wave flume was used in the tests and three types of nonwoven geotextiles and a conventional granular layer were employed as filters between the armour layer and the base soil slope. The armoured slope was subjected to the impacts of waves produced by a wave generator opposite to the channel slope. Pore pressures in the soil slope were measured during the tests and soil particles that piped though the filters and that were entrapped in the geotextile were collected for total mass and particle diameter measurements. The results obtained showed that the geotextile and the granular filters presented similar performance. In addition, retention criteria available for this type of geotextile filter application provided very conservative results. The findings highlight the importance of the development of more accurate testing techniques and filter criteria for designing armoured slopes with geotextile filters.



## 1. Introduction

Geosynthetic have been extensively used in different types of geotechnical and geoenvironmental structures fulfilling functions such as reinforcement, drainage, filter, separation, barriers and protection. Among other applications, geotextile filters can be used in revetments of channels, armoured banks of reservoirs and rivers and along the coast line. Erosion along coastlines can cause great damages to the environment and to neighbouring structures. The consequences of global warming and climate changes on tides, floods and waves will certainly increase erosion intensity along the coast in many countries in the next decades. The use of a geotextile filter in revetments and in armoured slopes provides several advantages with regard to traditional granular materials, such as quick and easy transportation and installation on site, less dependency on specialized labour and reduction in the exploitation of natural materials, besides other economic and environmental benefits. Among the latter one can mention the reduction of emissions of harmful gases to the atmosphere. Frischknecht et al. (2012) report significant benefits in the use of geosynthetics in different geotechnical and geoenvironmental works with respect to the reduction in carbon footprint.

Geotextiles can be used in erosion control works as silt fences and filters under revetments (Koerner, 2005; Farias et al., 2006). The action of waves can severely damage unprotected coastal slopes and river banks. The waves can be formed due to natural causes, as the action of winds or ground movements (seismic events), or due to human activities like the traffic of boats. The wave impact on the slope causes pore pressure increases close to its surface and the seepage in the slope has a cyclic nature with reversion of flow sense, which can influence filter behaviour (Chen et al., 2008a; Faure et al., 2010). These factors can cause instability of the armour layer and of the slope if an efficient filter is not present between the former and the base soil. In such applications a geotextile filter is subjected to severe flow conditions, which may compromise its retention capability or cause its clogging if the formation of bridges of particles around its openings is hampered due to the cyclic flow. The situation may be worsened because of river or ocean water level fluctuations caused by tides or in dry periods.

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Wave impacts can cause significant increases in pore pressures close to a slope surface, which may lead to larger values of hydraulic gradients in that region. Young et al. (2008) observed liquefaction of an unprotected sand slope in experimental and numerical analysis of the effects of a single wave of a tsunami. According to these authors the pore pressure increases in the slope are a consequence of compression of the soil mass caused by the wave impact and water seepage. Oumeracy and Partenscky (1990) examined the influence of wave height on the pore pressure generated in a large scale model of a breakwater with a granular filter. The greater the wave height the greater the excess pore pressure generated due to wave impact.

Several filter requirements have been established by different authors for the use of geotextile filters under cyclic flow conditions (Heerten, 1982; Lawson, 1982; Ingold, 1985; Chen and Chen, 1986; Luettich et al., 1992; Holtz et al., 1997; Hameiri, 2000; Mlynarek, 2000; Aydilek, 2006; for instance). Pulsating and cyclic flow experiments have also been carried out to investigate the performance of geotextile filters under such conditions (Cazzuffi et al., 1999; Fannin and Pishe, 2001; Chen et al., 2008a; Srikongsri and Fannin, 2011; for instance).

Chen et al. (2008b) performed filtration tests with cyclic flow and concluded that overburden pressure and the fine soil content play important roles in filtration, soil boiling and settlement behaviour of a soil-geotextile filtration system. Image analysis showed that soil clogging under cyclic flows was not so serious as that under unidirectional flows and that a particle bridging network can be formed under long-term cyclic flows in the areas near the filter that are not supported by the soil particles.

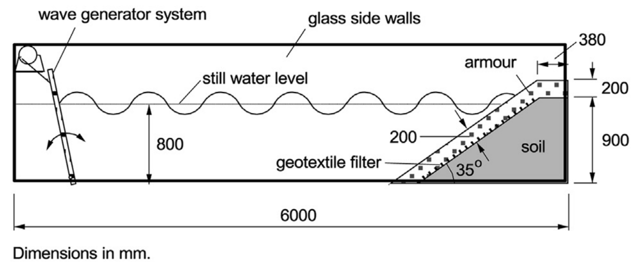
Faure et al. (2010) conducted large scale experiments using a wave flume to investigate geotextile filter behaviour under a revetment. Theses authors concluded that a thick geotextile with low number of constrictions would be suitable for bank protection under cyclic flow conditions. They also highlighted the importance of good quality contact between soil and geotextile in this type of application. Furthermore, the authors state that an appropriate design criterion should consider criteria other than filtration opening size, such as the remaining hydraulic conductivity, the energy of wave action and the stability of the slope.

The erosion mechanism due to wave impact is very complex, particularly if the waves tend to break on the slope (PIANC, 1987). To investigate this type of problem closer to field conditions tests using wave flumes have been conducted (Yasuhara and Recio-Molina, 2007; Recio and Oumeraci, 2007; Cantelmo et al., 2010; Faure et al., 2010). Making use of the benefits of carrying out large scale experiments, this paper presents and discusses the performance of geotextile and granular filters in slopes subjected to the action of waves using a large scale wave flume equipment. The study involved the use of different types of nonwoven geotextile filters and base soils under armour rocks subjected to controlled shocking waves.

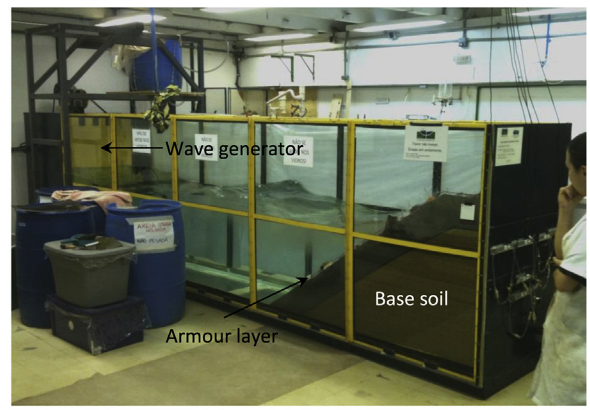
## 2. Test program

### 2.1. Equipment and test methodology

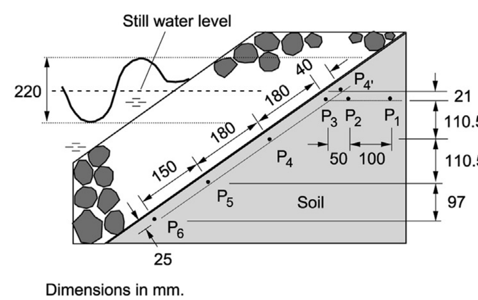
A channel was assembled for the tests. Fig. 1(a) presents the geometrical characteristics of the channel and Fig. 1(b) shows a general view during one of the tests performed. The dimensions of the channel are 6.0 m (length) × 1.5 m (height) × 1.0 m (width). The slope to be tested is constructed at one of the channel ends, whereas at the other end there is a wave generator (Fig. 1a). For the tests reported in this work the waves were 220 mm high, with length equal to 2.0 m and a frequency of 1.1 Hz. For such conditions the waves broke on the armour layer, with approximately 3000 impacts of waves per hour on the slope. The side walls of the tank consisted of glass panels (Fig. 1b) that allowed visualizing the development of erosive mechanisms during the tests. These walls also allowed filming and photographing the slope during the tests. A geotextile layer was used between the armour layer and the internal channel side walls. This geotextile layer avoided piping of base soil particles along the interface between the armour layer and the glass walls.




(a) Geometrical characteristics of the equipment.




(b) View of one of the tests.




(c) Location of pore pressure transducers.

**Fig. 1.** Experimental setup.

Pore pressure transducers were installed at different locations along the centre line of the soil slope to assess pore pressure variations during the experiments. Fig. 1(c) shows the locations of the pore pressure transducers. The installation of transducers was mainly concentrated in the region where the shocks of the waves took place. In this region the intensity of wave impact and the effects of reverse water flow are greater, which subject the filter to more critical operational conditions. A data acquisition system coupled with a microcomputer acquired and processed the readings from the transducers.

Additional tests on the materials consisted of grain size distribution and mass determinations of the soil particles that piped