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A bedload trap for aeolian sand transport

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ABSTRACT

This paper describes a bedload trap designed to separate bedload from saltation load in aeolian environments. The trap is installed below the sand surface and features a chimney that can be adjusted to the height of the surface. The chimney houses an internal wall to separate saltation load from bedload. Bedload particles are funneled to a piezo-electric sensor that converts grain impacts to voltages that can be sampled at very high frequencies (44,000 Hz in this example). Grains are then collected in a container that is easily retrieved so that sand samples can be obtained for weighing and subsequent grain size analysis. An algorithm to isolate single grain impacts is described. The version of the trap presented here is intended for the study of the initiation of grain motion.

1. Introduction

The methods for effectively trapping wind-blown sand have advanced considerably over the last century, with an emphasis on developing traps to measure saltation load (Leatherman, 1978; Arens and van der Lee, 1995; Namikas, 2003). Methods intended to capture only bedload are less well developed, hindering the execution of bedload-specific studies in aeolian systems, as discussed in Wang and Zheng (2004) and Wang et al. (2009). This deficiency limits our understanding of bedload transport dynamics. One consequence of this failing is uncertainty concerning the proportion of total sand transport that moves as bedload rather than saltation (Anderson et al., 1991; Tsoar, 1994; Wang and Zheng, 2004; Han et al., 2012; Zhang et al., 2012).

We have designed a trap to capture aeolian bedload while minimizing contamination of trapped samples with grains that are moving via saltation. The trap has three main components: (1) a chimney that segregates saltation from bedload; (2) a piezo-electric sensor that detects grain impacts and can be sampled at high frequencies; and (3) a sand collection vessel that can be retrieved for sample weighing and grain size analysis. The configuration described herein was designed for use with transport conditions at or near the threshold of motion.

Bedload transport consists of particles that roll, slide or move in small hops over the surface driven either by the direct force of the wind on the grains or as a result of bombardment from saltating particles (Bagnold, 1937a,b; Leatherman, 1978; Anderson, 1987). The movement of particles in small hops is often referred to as reptation, and is sometimes considered to be a mode of transport intermediate from bedload and saltation (Willetts and Rice, 1989; Anderson et al., 1991; Kok et al., 2012). The term, derived from the Latin verb *reptare*, meaning 'to crawl' (as in reptile), is also used interchangeably with bedload, or creep (Mitha et al., 1986; Ungar and Haff, 1987; Werner and Haff, 1988; Werner, 1990; Welland, 2011; Lämmel et al., 2012). Some define reptation as a mode of, or synonymous with, bedload transport (Bagnold, 1937a,b; Owen, 1964; Leatherman, 1978; Anderson, 1987; Ellis and Sherman, 2013), and we follow this latter usage.

An early reference to a bedload-specific trap is from Bagnold (1937b). Bagnold's trap was built into the floor of a wind tunnel. The 5 by 20 mm, flow-transverse aperture was set below the surface at a distance equivalent to the thickness of the sand, and was liable to capture both saltation and bedload (Anderson et al., 1991; Tsoar, 1994; Wang et al., 2009). Bagnold (1937b) identified all sand captured in the trap as bedload, and reported bedload as comprising 25% of the total transport; an estimate still used in some aeolian studies (Welland, 2011; Zhang et al., 2012). Others, including Anderson et al. (1991) and Tsoar (1994), consider Bagnold's value to be an over-estimation arising from the trap design. The trap presented here minimizes the contamination of saltation using a surface-flush chimney that internally separates bedload from saltation and is vertically adjustable to accommodate changing bed elevations. Bedload transport is measured at high frequencies using a piezo-electric sensor, and subsequently guided into collection vessels.

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2. Bedload trap design

The trap (Figs. 1 and 2) was fabricated with a precipitation hardened, ¼" aluminum alloy (6061-T6 Al). The alloy is strong enough to survive stresses associated with long distance shipping and deployment in rigorous field conditions, while still allowing precision welding (a tolerance of about 1 mm) during fabrication. Reinforcement walls (Fig. 2a) and a detachable door with a silicone rubber seal prevent water and sediment from entering the interior of the trap housing. The housing has a circular outlet 15.6 mm in diameter with an adaptable compression fitting to accommodate power and signal cables and protect them from damage that might result from the stress of installation during multiple field deployments (Fig. 2b).

Within the case, there is space for sample vessels to collect the segregated bedload and, if desired, saltation load (Fig. 2c). Moving sand enters the trap via a surface-flush chimney aperture (Figs. 3 and 4). Sand is led from the aperture to the vessels through a bifurcated chimney (Figs. 3 and 4). The position of the aperture (a 20 by 20 mm opening at the top of the chimney) is adjustable through a vertical range of 100 mm so that the aperture can be adjusted to remain flush with the sand surface. After adjustment the chimney is secured with sliding thumb screws along a double slotted wall in the outer housing. The side of the chimney intended to collect bedload includes a built-in funnel to guide grains to the face of a piezoelectric impact sensor, aka Buzzer Disk, as described by Li, 2010 and Sherman et al. (2011), that registers the grain impact. The sensor is tilted at an angle of 45° so that grains bounce off the face rather than accumulate. The resulting signal is amplified through a printed circuit board and transmitted to a data acquisition system.

The main function of the partition within the chimney is to segregate grains moving as bedload from those moving in saltation. The design is based on the concept that saltating grains over a flat surface typically impact the bed at angles less than 16° (results of trajectory experiments supporting this concept are summarized in Table 1). Therefore, saltation load should enter a surface-flush aperture at similar angles. A particle moving as bedload would fall into the opening at an angle with the surface much closer to 90° (Fig. 4).

We used this information to position the upper edge of a wall that bifurcates the chimney at a point 10 mm below the trap opening and 10 mm from the windward chimney sidewall, producing an angle of 45° between the upper edge of the aperture and the chimney divider. The angle of separation was increased from 16° to 45° for this version of the trap to provide a conservative margin of error for the impact angles. Saltating grains should pass above the divider and fall into a collecting vessel. Bedload particles should fail to clear the divider and be funneled to a 6.5 mm diameter Buzzer Disk (Audiowell Electronics (Guangzhou) Co., Ltd, Model AW1E6.5T-135E). After impacting the Buzzer Disk, grains are funneled through a 4 mm diameter funnel to a non-static tube

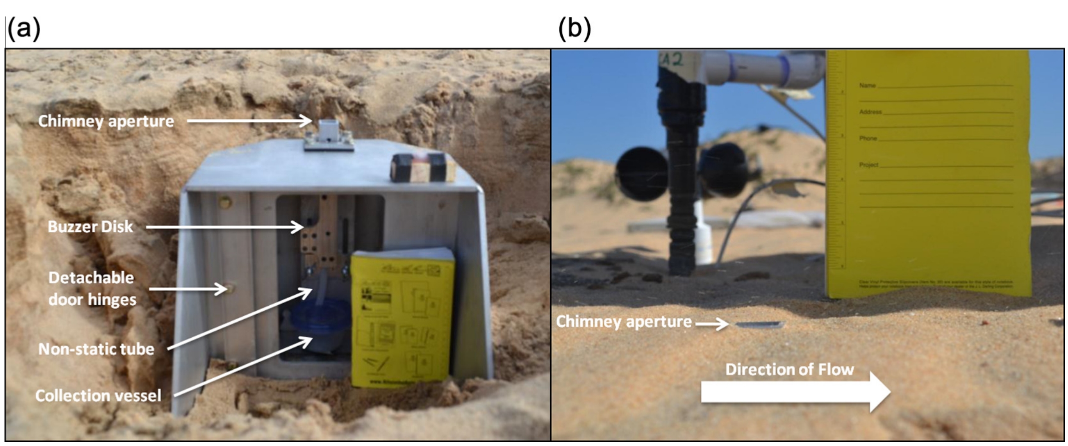

Fig. 1. (a) An image showing the trap before burial; and (b) an image showing the trap during data collection.

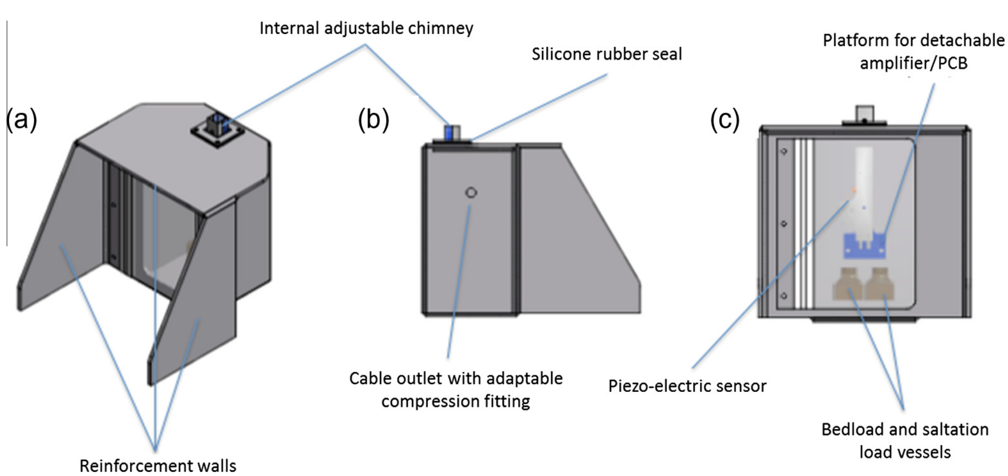

Fig. 2. From left to right: (2a) outer case with reinforcement walls to reduce sand deposition at access point; (2b) cable outlet with compression fitting and silicone rubber seal; and (2c) adjustable internal chimney with funnels and collection vessels for bedload and saltation transport and platform for detachable amplifier or printed circuit board. Further detail presented in Figs. 3 and 4.