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A high-efficiency, low-cost aeolian sand trap

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ABSTRACT

We present a design for an aeolian sand trap that is based on the streamer trap concept used in sediment transport studies. The trap is inexpensive, has excellent trapping efficiency, is durable, and easy to use. It is fabricated from stainless steel that is cut and bent to form a frame to support a fine nylon mesh. Typical trap openings are 100 mm wide and 25, 50, or 100 mm high. Traps are 250 mm long, and are stackable to measure vertical characteristics of saltation. The nylon mesh has 64 μm openings that comprise 47% of the area of the material. Aerodynamic efficiency was tested in a wind tunnel, and sediment trapping efficiency evaluated in field deployments. Both evaluations support the use of this trap for short-term measurements.

1. Introduction

The ability to measure aeolian sand transport in natural environments has advanced rapidly over the last few decades. Electronic devices have been a major focus of effort, from the development of continuous-weighing sand traps (Fryberger et al., 1979; Lee, 1987; Jackson, 1996; Bauer and Namikas, 1998), to an array of different saltation impact sensors (Stockton and Gillette, 1990; Spaan and Van den Abele, 1991; Baas, 2004; Ellis et al., 2009; Li, 2010; Swann and Sherman, 2013), to laser-based sensors (Mikami et al., 2005; Davidson-Arnott et al., 2008). The motivation for these innovations has been to measure transport at temporal scales commensurate with those common to modern anemometry. For many applications, however, there remains a need for a high-efficiency, low-cost, sand trap such as that described herein.

The advantages of continuous-weighing sand traps include the ability to produce accurate and temporally detailed records of sand transport. There are some disadvantages, however. These traps include apparati that must be installed beneath the sand surface. Near-surface water table in some coastal environments will prevent such installation. In dry environments, care must be taken to keep the trap opening aligned with the transport surface – a sometimes difficult task when there is substantial aeolian sand transport, leading to potential scour or deposition around the trap. These traps also require a power supply and some form of data acquisition and storage. Because of the installation requirements, continuous-weighing traps cannot be quickly and easily relocated and may require field calibration (e.g., Bauer and Namikas, 1998).

Saltation sensors of any type measure the intensity of grain transport at high-frequencies (10 kHz or faster) in very small areas (less than 100 mm^2). Their advantages include the ability to provide detailed information regarding the time and space characteristics of saltation, especially in the context of transport unsteadiness (e.g., Ellis et al., 2012). These sensors require a power supply and some form of data acquisition and recording. Because they are relatively small and are installed above the sand surface, these devices are easy to deploy and can be moved to different locations quickly, depending on how they are tethered to support devices (power supply or data acquisition). The main disadvantages to these sensors is that they cannot be used to measure sand transport rates without contemporaneous sand trapping so that saltation rates can be calibrated against measured rates or converted to transport rates using appropriate grain size information from trapped samples. One exception to this is the laser-based system developed by Mikami et al. (2005). This system, however, is very expensive, and does not provide grain size information that is immediately consistent with sieve or fall column estimates of grain sizes (Ellis and Sherman, 2013). Additionally, all saltation sensors are liable to signal saturation under conditions of intense saltation (Sherman et al., 2011).

There have been several basic designs for static, or passive, sand traps, and these have been discussed and tested extensively in the literature (Leatherman, 1978; Arens and van der Lee, 1995; Nickling and McKenna Neuman, 1997; Goossens and Offer, 2000; Namikas, 2002; Li and Ni, 2003; Dong et al., 2004; Cabrera and

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Alonso, 2010) and will not be discussed herein. The basic designs for vertically-oriented traps are cylindrical (e.g., Leatherman, 1978; or Rosen, 1978), wedge-shaped (e.g., Illenberger and Rust, 1986; or Nickling and McKenna Neuman, 1997), or box-shaped, with or without vertical segregations (e.g., Bagnold, 1938; Pease et al., 2002; or Dong et al., 2004). These traps require burial of a collecting chamber, are of unknown efficiency, with complicated or expensive construction, or some combination of the foregoing. Here we describe a box-shaped trap intended to circumvent these restrictions.

We have designed a mesh-style sand trap to obtain information on time-integrated transport rates, vertical saltation flux profiles, vertical distributions of grain size, and to complement the use of saltation sensors, especially for the calibration of sensor data to estimate transport rates. It is designed specifically for short-term deployments – typically less than 900 s. The sample duration is limited by the transport rate because of the growth of the sand deposit within the trap that will progressively reduce trap efficiency – a trait common to almost all static traps. The traps are easily removed (to be emptied), replaced, or relocated because they sit directly on the sand surface (or in stacks). This is an advantage over static trap designs that require part of the installation to be below the surface, such as those described by Leatherman (1978), Rosen (1978), Nickling and McKenna Neuman (1997) or Namikas (2002), among others.

2. Design and materials

The design of this trap derives from coincident objectives to produce a trap that is: (1) highly efficient; (2) low cost; (3) easily portable; (4) durable; (5) of uniform dimensions; and (6) able to be stacked vertically. The concept of the trap plays off the characteristics demonstrated in the high-efficiency streamer traps used in nearshore sediment transport studies (e.g., Kraus, 1987; Rosati and Kraus, 1988; Tonk and Masselink, 2005; Nordstrom et al., 2006) and the prototype hose traps (Pease et al., 2002) first used in the AEOLUS program (Sherman et al., 1994).

The trap frame is cut and bent from a single sheet of 1 mm thick, stainless steel (Fig. 1). The cut-outs are to increase airflow through the trap. The holes could be larger, but increasing their size will reduce the strength of the trap and, thus, durability. After bending, the over-lapping edges are welded, with the raised seam on the outside of the trap so that all external, longitudinal corners are smooth, and so that the 100 mm internal width is maintained. It is possible to construct the frame with separate pieces, but this produces rough corners that could damage the mesh covering. We have had the frames made in three configurations. All configurations are 100 mm wide and 250 mm long, and have heights of 25, 50, or 100 mm. The version depicted in Fig. 1 is 25 mm high. One of the objectives in efficient trap design is to obtain a ratio of the area of the trap opening to the frame's exterior, cross-section area as close to 1.00 as possible. A ratio of 1.00 can occur only when the frame materials have no width. For this trap design, the respective ratios are 0.91, 0.94, and 0.96 for the 25, 50, and 100 mm high traps. The frames were manufactured by Basis Solutions, LLC, of Bryan, TX at a cost of $38, $39, and $41 each, for the three sizes, respectively. If precision and durability are not important issues for a particular project, a frame could be built with wood or plastic, allowing for DIY construction.

The frame is covered with nylon mesh that is attached with adhesive. The width of the cut mesh will vary according to the trap dimensions, but must include enough extra width to provide an overlap on a frame corner to allow additional adhesion. The length of the mesh that we used was 500 mm. The additional length is used to form an open fabric tube behind the frame that can be closed with a metal clamp. Sand blows through the trap and accumulates in the tube. The clamp can be opened so that the trap can be emptied for sample collection.

There are a variety of mesh configurations commercially available. We used a 64/47 nylon mesh. The '64' refers to the width of the mesh openings – 64 micrometers. This size opening corresponds closely with the 63 micrometer definition ISO 14688 (ISO 2002), the transition from silt (finer) to very fine sand (coarser). Thus very little sand should pass through the material. The '47' refers to the percentage of the fabric that comprises the openings. This is the most "open" mesh we could identify.

3. Trap efficiency

We tested the aerodynamic efficiency of the traps in the Oran W. Nicks Low Speed Wind Tunnel at Texas A&M University. We used a pair of thermal anemometers (Dantec Dynamics) to

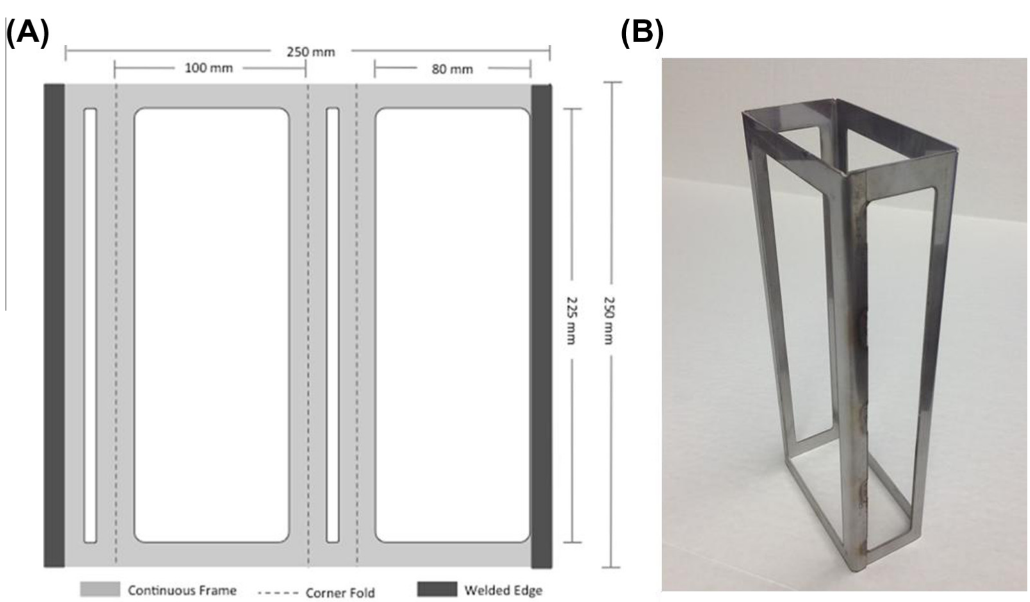

Fig. 1. (A) Schematic of the trap frame showing dimensions for 100 × 25 mm opening. Frame is machine bent along dotted lines and welded (external overlap) to join the darkened strips. (B) Bent and welded frame without mesh.